JOURNAL OF THE AERONAUTICAL SCIENCES

VOLUME 3 NUMBER 11

SEPTEMBER, 1936

Published by the

INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.

INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.

President
GLENN L. MARTIN

Past Presidents
J. C. HUNSAKER
CHARLES L. LAWRANCE
D. W. DOUGLAS

Vice Presidents
EDWIN E. ALDRIN
C. L. EGTVEDT
G. W. LEWIS
CLARK B. MILLIKAN
EUGENE E. WILSON

Treasurer
SHERMAN M. FAIRCHILD
Secretary
LESTER D. GARDNER
Assistant Secretary
GEORGE R. FORMAN
Comptroller
C. E. SINCLAIR

COUNCIL

EDWIN E. ALDRIN
CHARLES H. CHATFIELD
CHARLES H. COLVIN
LUIS DE FLOREZ
SHERMAN M. FAIRCHILD
JAMES H. KIMBALL
PAUL KOLLSMAN
CHARLES L. LAWRANCE
ARTHUR NUTT
EARL D. OSBORN
ELMER A. SPERRY, JR.
T. P. WRIGHT

ADVISORY BOARD

EDMUND T. ALLEN
VINCENT BENDIX
LYMAN J. BRIGGS
V. E. CLARK
J. H. DOOLITTLE
JACK FRYE
W. R. GREGG
LEROY R. GRUMMAN
HALL L. HIBBARD
J. H. KINDELBERGER
E. J. KING
ALEXANDER KLEMIN
I. MACHLIN LADDON
GROVER LOENING
JOHN K. NORTHROP
A. A. PRIESTER
A. E. RAYMOND
H. J. E. REID
JAMES M. SHOEMAKER
E. A. STALKER
GERARD F. VULTEE
O. WESTOVER

JOURNAL OF THE AERONAUTICAL SCIENCES

VOL. 3 SEPTEMBER, 1936 NO. 11

Editor: J. C. HUNSAKER, *Massachusetts Institute of Technology*

PUBLISHED MONTHLY BY THE INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.
AT 99–129 NORTH BROADWAY, ALBANY, NEW YORK

The JOURNAL OF THE AERONAUTICAL SCIENCES is the official publication of the Institute of the Aeronautical Sciences, Inc., and is devoted to papers on experimental, theoretical, and applied science as employed in aeronautics.

Manuscripts for publication, proofs, and all correspondence should be addressed to the Editorial Secretary of the JOURNAL. Subscription price: $5.00 per year; single copies, 50c. Foreign subscription price: $6.00 per year; single copies, 60c.

Correspondence regarding subscriptions may be addressed to Publication Office, 99–129 North Broadway, Albany, N. Y., or to the Editorial Office of the JOURNAL OF THE AERONAUTICAL SCIENCES, 5431 R. C. A. Building, Rockefeller Center, New York, New York. Cable Address: INSAEROSCI.

Entered as Second Class Matter at Post Office, Albany, N. Y., October 2, 1935. Acceptance for mailing at a special rate of postage provided for in the Act of October 3, 1917, embodied in paragraph 4, section 412, P. L. & R. authorized February 17, 1934.

JOURNAL OF THE AERONAUTICAL SCIENCES

CONTENTS

The Kinetic Energy of a Body of Revolution Moving in an Infinite Fluid . . . . CARL KAPLAN 381

Airplane Tracks in the Surface of Stratus Clouds . . . . . IRVING LANGMUIR AND ALEXANDER FORBES 385

Elastic Stability of Plane Frameworks . . . . . W. PRAGER 388

Lateral Control Design . . . . . ARTHUR G. B. METCALF 393

The Helicopter: Propulsion and Torque . . . . . HAVILAND H. PLATT 398

Change of Boiling Point of Liquid Oxygen at High Altitudes . . . . JEAN PICCARD 406

Engineering Applications of Boundary Layer Control . . . . . RAYMOND B. MALOY 407

Letters to the Editor . . . . . LUIS DEFLOREZ, JAMES B. TAYLOR, JR. 410

Institute Notes 411

Exchanges 412

Aeronautical Reviews 413

Book Reviews

Die Flugzeugfuehrer, (*Dipl.-Ing. Otto R. Thomsen*) 387

Die Fliegerschuetz, (*Major W. V. Cornberg*) 387

Climatic Maps of North America, (*Charles F. Brooks, A. J. Connor and others*) . . . . J. C. Hunsaker 397

Books Received 387

VOLUME 3 SEPTEMBER, 1936 NUMBER 11

An Appreciation

to

Corporate Members

of the

Institute of the Aeronautical Sciences

The publication of the Journal of the Aeronautical Sciences is made possible by Corporate Members who are manufacturers or operators of aircraft or producers of equipment or supplies used in aeronautics who contribute annually to the Institute.

The dues of Corporate Members range from a minimum of $200 to a maximum of $2500.

The income from these dues enabled the Institute to discontinue advertisements in the Journal and use the pages for editorial material. The Members of the Institute appreciate the cooperation of Corporate Members in providing funds for assisting the work of the Institute and for the publication of the Journal.

Aluminum Company of America
Gulf Building, Pittsburgh, Pennsylvania

Bellanca Aircraft Corporation
New Castle, Delaware

The B. G. Corporation
136 W. 52nd Street, New York, N. Y.

Curtiss-Wright Corporation
30 Rockefeller Plaza, New York, N. Y.

- Curtiss Aeroplane & Motor Company
  Buffalo, New York
- Curtiss-Wright Airplane Company
  Robertson, Missouri
- Wright Aeronautical Corporation
  Paterson, New Jersey

Douglas Aircraft Company
Santa Monica, California

Eclipse Aviation Corporation
East Orange, New Jersey

Edo Aircraft Corporation
College Point, Long Island, New York

Ethyl Gasoline Corporation
135 East 42nd Street, New York, N. Y.

Fairchild Aviation Corporation
30 Rockefeller Plaza, New York City

- Fairchild Aircraft Corporation
  Hagerstown, Maryland
- Fairchild Aerial Camera Corporation
  Woodside, Long Island, New York
- Fairchild Aerial Surveys, Inc.
  Los Angeles, California
- Ranger Engineering Corporation
  Farmingdale, Long Island, New York

General Tire & Rubber Company
Akron, Ohio

Glenn L. Martin Company
Baltimore, Maryland

The Goodyear Tire & Rubber Company
Akron, Ohio

Gulf Oil Corporation
Gulf Building, Pittsburgh, Pa.

Kollsman Instrument Company
1 Junius Street, Brooklyn, New York

The Northrop Corporation
Inglewood, California

Shell Eastern Petroleum Products
50 West 50th Street, New York, N. Y.

Shell Oil Company
Shell Building, San Francisco, California

Shell Petroleum Corporation
Shell Building, St. Louis, Missouri

Socony-Vacuum Oil Company
26 Broadway, New York, N. Y.

Sperry Gyroscope Company
Manhattan Bridge Plaza, Brooklyn, New York

Stanavo Specification Board
26 Broadway, New York, N. Y.

Summerill Tubing Company
Bridgeport, Montg. Co., Pennsylvania

The Texas Company
135 East 42nd Street, New York, N. Y.

Transcontinental & Western Air
Municipal Airport, Kansas City, Mo.

United Aircraft Corporation
East Hartford, Connecticut

- Chance Vought Aircraft
  East Hartford, Connecticut
- Hamilton Standard Propellers
  East Hartford, Connecticut
- Pratt & Whitney Aircraft
  East Hartford, Connecticut
- Sikorsky Aircraft
  Bridgeport, Connecticut

JOURNAL OF THE AERONAUTICAL SCIENCES

Volume 3 SEPTEMBER, 1936 Number 11

The Kinetic Energy of a Body of Revolution Moving in an Infinite Fluid

CARL KAPLAN, *National Advisory Committee for Aeronautics*

(Received August 28, 1936)

SUMMARY

A BODY of revolution is assumed to move rectilinearly in a perfect fluid, and the motion imparted to the fluid separated into its axial and transverse components. The velocity potentials for these two types of motion are well known and may be expressed in series of ellipsoidal harmonics. Analogous to a general theorem given by G. I. Taylor, it is then shown in a simple manner that the kinetic energy of the fluid external to the moving body depends only on the coefficients of the first terms of the aforementioned series and on the volume of the moving body.

INTRODUCTION

A general result obtained by G. I. Taylor[1] showed that if the velocity potential of the fluid external to a body moving without rotation be represented by a series of spherical harmonics, then the kinetic energy of the fluid depends only on the harmonic terms of the first degree in the expansion for the velocity potential and on the volume of the moving body. In the present note this interesting result is reexamined in connection with the rectilinear motion of bodies of revolution.

It is well known that, when a body of revolution moves without rotation, the motion imparted to the fluid may be regarded as made up of two component motions —an axial flow and a transverse flow. The respective velocity potentials are given by the following expressions:

$$\left.\begin{aligned}\Phi_a &= \sum_{n=1}^{\infty} A_n P_n(\mu) Q_n(\lambda) \\ \Phi_t &= \sum_{n=1}^{\infty} B_n P_n^1(\mu) Q_n^1(\lambda)\end{aligned}\right\} \tag{1}$$

where $P_n(\mu)$, $Q_n(\lambda)$ are respectively Legendre functions of degree n of the first and second kinds; and $P_n^1(\mu)$, $Q_n^1(\lambda)$ are respectively associated Legendre functions of degree n and order 1 of the first and second kinds.[2]

The kinetic energy T of the fluid may be obtained from the following surface integral:

$$\frac{2T}{\rho} = -\int_i \int \Phi \frac{\partial \Phi}{\partial n} d\sigma \tag{2}$$

where the suffix i indicates that the integration extends over the surface of the moving body and $\partial\Phi/\partial n$ denotes the component of the vector $\overline{\text{grad}}\ \Phi$ in the direction of the outward drawn normal to the surface of the moving body.

Furthermore if U, V are respectively the axial and transverse components of the velocity of the body then the kinetic energy of the fluid may be written as:

$$\frac{2T}{\rho} = AU^2 + BV^2 \tag{3}$$

the term involving UV vanishing because of the longi-

[1] G. I. Taylor, *The Energy of a Body Moving in an Infinite Fluid with an Application to Airships*, Proc. Roy. Soc., Series A. 120, August 1928, pp. 13-21.

[2] H. Lamb, *Hydrodynamics*, Fifth Edition, Cambridge University Press, 1924, pp. 132, 133.

tudinal symmetry of a body of revolution. In what follows it will be shown that A, B depend respectively only on the coefficients A_1, B_1 of the velocity potentials Φ_a, Φ_t and on the volume v of the body. The proof of this result involves the use of Green's second theorem, which states that

$$\int_i\int\left(\psi_1\frac{\partial\psi_2}{\partial n}-\psi_2\frac{\partial\psi_1}{\partial n}\right)d\sigma=\int_o\int\left(\psi_1\frac{\partial\psi_2}{\partial n}-\psi_2\frac{\partial\psi_1}{\partial n}\right)d\sigma \quad (4)$$

where the suffixes i, o denote respectively integration over the inner and outer bounding surfaces and where ψ_2, ψ_1 are two functions satisfying Laplace's equation in the region of integration.

Replacing Φ by $\Phi_a + \Phi_t$, Eq. (2) takes the form

$$\frac{2T}{\rho}=-\int_i\int\Phi_a\frac{\partial\Phi_a}{\partial n}d\sigma-\int_i\int\Phi_t\frac{\partial\Phi_t}{\partial n}d\sigma-2\int_i\int\Phi_t\frac{\partial\Phi_a}{\partial n}d\sigma \quad (5)$$

where the last term on the right-hand side is obtained by virtue of the reciprocal relation:

$$\int_i\int\Phi_a\frac{\partial\Phi_t}{\partial n}d\sigma=\int_i\int\Phi_t\frac{\partial\Phi_a}{\partial n}d\sigma$$

CALCULATION OF $\int_i\int\Phi_a\,\partial\Phi_a/\partial n\,d\sigma$

The boundary condition for axial flow is given by

$$-\frac{\partial\Phi_a}{\partial n}=lU$$

where l is the direction cosine with regard to the X axis of the normal drawn from the surface of the moving body into the fluid.

It follows then that

$$-\int_i\int\Phi_a\frac{\partial\Phi_a}{\partial n}d\sigma=U\int_i\int l\Phi_a\,d\sigma$$

Suppose now the moving body to be enclosed by an outer surface, and apply Green's theorem by choosing $\psi_1 = Ux$ and $\psi_2 = \Phi_a$. Eq. (4) then becomes:

$$\int_i\int\left(-lU^2x-U\Phi_a\frac{\partial x}{\partial n}\right)d\sigma=\int_o\int\left(Ux\frac{\partial\Phi_a}{\partial n}-U\Phi_a\frac{\partial x}{\partial n}\right)d\sigma$$

Replacing $\int_i\int xl\,d\sigma$ by v (the volume of the body) and $\partial x/\partial n$ by l, the above equation becomes:

$$U\int_i\int l\Phi_a d\sigma=-U^2\cdot v-U\int_o\int\left(x\frac{\partial\Phi_a}{\partial n}-l\Phi_a\right)d\sigma \quad (6)$$

The choice of the outer surface is arbitrary but it suggests itself, in view of the fact that the velocity potentials are expressed in terms of spheroidal coordinates, to choose one of the members of the confocal system of closed coordinate surfaces (ellipsoids of revolution about the X axis) belonging to this system of coordinates, say the one defined by $\lambda = \lambda_0$. This being done the next step is to express the integrand of the surface integral on the right-hand side of Eq. (6) in terms of spheroidal coordinates.

The equations of transformation from rectangular Cartesian coordinates to spheroidal coordinates are as follows:

$$\left.\begin{aligned}x&=k\lambda\mu\\ y&=k(\lambda^2-1)^{1/2}(1-\mu^2)^{1/2}\cos\omega\\ z&=k(\lambda^2-1)^{1/2}(1-\mu^2)^{1/2}\sin\omega\end{aligned}\right\} \quad (7)$$

Then choosing as parametric curves of the surface $\lambda = \lambda_0$, the orthogonal coordinate lines ω = variable, μ = constant (circles with center on the X-axis) and ω = constant, μ = variable (ellipses formed by the intersection of the surface $\lambda = \lambda_0$ and the meridian planes ω = constant), it follows, since the element of surface is given by $ds_\omega\,ds_\mu$ and l by $\partial(y, z)/\partial(ds_\omega, ds_\mu)$ that:

$$l\,d\sigma=\frac{\partial(y,z)}{\partial(ds_\omega,ds_\mu)}ds_\omega,\,ds_\mu$$

and

$$\frac{\partial\Phi_a}{\partial n}d\sigma=\frac{\partial\Phi_a}{\partial s_\lambda}ds_\omega ds_\mu$$

From the equations of transformation (7) it may be shown that

$$ds_\mu=k\left(\frac{\lambda^2-\mu^2}{1-\mu^2}\right)^{1/2}d\mu$$
$$ds_\lambda=k\left(\frac{\lambda^2-\mu^2}{\lambda^2-1}\right)^{1/2}d\lambda$$
$$ds_\omega=k(1-\mu^2)^{1/2}(\lambda^2-1)^{1/2}\,d\omega$$

Hence

$$\left.\begin{aligned}&l\,d\sigma=k^2\mu(\lambda^2-1)\,d\omega d\mu\\ \text{and}\quad&\frac{\partial\Phi_a}{\partial n}d\sigma=k(\lambda^2-1)\frac{\partial\Phi_a}{\partial\lambda}d\omega d\mu\end{aligned}\right\} \quad (8)$$

Substituting for Φ_a from Eq. (1) and making use of Eq. (8), the integral over the outer surface appearing on the right-hand side of Eq. (6) becomes:

$$\int_o\int\left(x\frac{\partial\Phi_a}{\partial n}-l\Phi_a\right)d\sigma=k^2(\lambda_0^2-1)\sum_{n=1}^{\infty}A_n\int_{o}^{2\pi}\int_{-1}^{1}$$
$$\times\left[\lambda_0\left(\frac{dQ_n}{d\lambda}\right)-Q_n(\lambda_0)\right]_{\lambda=\lambda_0}\mu\,P_n(\mu)\,d\omega\,d\mu$$

According to the definitions of the zonal harmonics of the first and second kinds:

$$\mu = P_1(\mu)$$

and

$$\lambda_0\left(\frac{dQ_1}{d\lambda}\right)_{\lambda=\lambda_0}-Q_n(\lambda_0)=-\frac{1}{\lambda_0^2-1}$$

Furthermore

$$\int_{-1}^{1}P_1(\mu)\,P_n(\mu)=\begin{cases}0 \text{ if } n\neq 1\\ \frac{2}{3}\text{ if } n=1\end{cases}$$

Therefore

$$\int_o\int\left(x\frac{\partial\Phi_a}{\partial n}-l\Phi_a\right)d\sigma=-\frac{4}{3}\pi k^2A_1$$

or from Eq. (6)

$$-\int_i\int\Phi_a\frac{\partial\Phi_a}{\partial n}\,d\sigma=-U^2\cdot v+\frac{4}{3}\pi\,Uk^2A_1 \quad (9)$$

Calculation of $\int_t\int \Phi_t \frac{\partial \Phi_t}{\partial n} d\sigma$

The boundary condition for transverse flow is given by

$$-\frac{\partial \Phi_t}{\partial n} = mV$$

where m is the direction cosine with regard to the Y-axis of the outward drawn normal to the surface of the moving body. Hence

$$-\int_t\int \Phi_t \frac{\partial \Phi_t}{\partial n}\, d\sigma = V\int_t\int m\Phi_t\, d\sigma$$

Then choosing $\psi_1 = Vy$ and $\psi_2 = \Phi_t$, Green's theorem yields the following:

$$\int_t\int \left(Vy\frac{\partial \Phi_t}{\partial n} - V\Phi_t\frac{\partial y}{\partial n}\right) d\sigma = \int_0\int \left(Vy\frac{\partial \Phi_t}{\partial n} - V\Phi_t\frac{\partial y}{\partial n}\right) d\sigma$$

and noting that

$$\frac{\partial y}{\partial n} = m,\quad \int_t\int my\, d\sigma = v$$

it follows that

$$V\int_t\int m\Phi_t\, d\sigma = -V^2 . v - V\int_0\int \left(y\frac{\partial \Phi_t}{\partial n} - m\Phi_t\right) d\sigma \quad (10)$$

Again, suppose the outer surface to be a spheroid defined by $\lambda = \lambda_0$. Then

$$m d\sigma = \frac{\partial(z, x)}{\partial(ds_\omega, ds_\mu)}\, ds_\omega\, ds_\mu = k^2\lambda\,(\lambda^2-1)^{\frac{1}{2}}\,(1-\mu^2)^{\frac{1}{2}} \cos\omega\, d\omega\, d\mu$$

and

$$\frac{\partial \Phi_t}{\partial n}\, d\sigma = k(\lambda^2-1)\frac{\partial \Phi_t}{\partial \lambda}\, d\omega\, d\mu \quad (11)$$

Substituting for Φ_t from Eq. (1) and making use of Eq. (11), the integral over the outer surface appearing on the right-hand side of Eq. (10) becomes:

$$\int_0\int \left(y\frac{\partial \Phi_t}{\partial n} - m\Phi_t\right) d\sigma = k^2\,(\lambda_0^2-1)^{\frac{1}{2}} \sum_{n=1}^{\infty} B_n \left[(\lambda_0^2-1)\times \left(\frac{dQ_n^1}{d\lambda}\right)_{\lambda=\lambda_0} - \lambda_0 Q_n^1(\lambda_0)\right] \int_0^{2\pi}\int_{-1}^{1} (1-\mu^2)^{\frac{1}{2}} P_n^1(\mu) \cos^2\omega\, d\omega\, d\mu$$

According to the definitions of the associated Legendre functions of the first and second kinds:

$$(1-\mu^2)^{\frac{1}{2}} = P_1^1(\mu)$$

and

$$(\lambda_0^2-1)\left(\frac{dQ_1^1}{d\lambda}\right)_{\lambda=\lambda_0} - \lambda_0 Q_1^1(\lambda_0) = \frac{2}{(\lambda_0^2-1)^{\frac{1}{2}}}$$

Also

$$\int_{-1}^{1} P_1^1(\mu)\, P_n^1(\mu)\, d\mu = \begin{cases} 0 \text{ if } n \neq 1 \\ \frac{4}{3} \text{ if } n = 1 \end{cases}$$

Therefore

$$\int_0\int \left(y\frac{\partial \Phi_t}{\partial n} - m\Phi_t\right) d\sigma = \frac{8}{3}\pi k^3 B_1$$

or from Eq. (10)

$$-\int_t\int \Phi_t \frac{\partial \Phi_t}{\partial n} d\sigma = -V^2 v - \frac{8}{3}\pi V k^3 B_1 \quad (12)$$

Calculation of $\int_t\int \Phi_t \frac{\partial \Phi_a}{\partial n} d\sigma$

The boundary condition for axial motion being $-\partial\Phi_a/\partial n = lU$, it follows that

$$-\int_t\int \Phi_t \frac{\partial \Phi_a}{\partial n} d\sigma = U\int_t\int l\Phi_t d\sigma$$

Then choosing $\psi_1 = Ux$ and $\psi_2 = \Phi_t$, Green's theorem yields:

$$\int_t\int \left(Ux\frac{\partial \Phi_t}{\partial n} - U\Phi_t\frac{\partial x}{\partial n}\right) d\sigma = \int_0\int \left(Ux\frac{\partial \Phi_t}{\partial n} - U\Phi_t\frac{\partial x}{\partial n}\right) d\sigma$$

and since

$$-\frac{\partial \Phi_t}{\partial n} = mV \text{ (on the surface of the moving body) and } \frac{\partial x}{\partial n} = l$$

it follows that

$$U\int_t\int l\Phi_t d\sigma = -UV\int_t\int mx\, d\sigma - U\int_0\int \left(x\frac{\partial \Phi_t}{\partial n} - l\Phi_t\right) d\sigma \quad (13)$$

According to Gauss' theorem

$$\int_t\int mx\, d\sigma = \int\int_\tau \int \frac{\partial x}{\partial y}\, d\tau = 0$$

Furthermore, when the integrand of the outer surface integral appearing on the right-hand side of Eq. (13) is expressed in terms of spheroidal coordinates it will be seen that cos ω appears to the first power only. Hence, since $\int_0^{2\pi} \cos\omega\, d\omega = 0$ it follows that:

$$-\int_t\int \Phi_t \frac{\partial \Phi_a}{\partial n} d\sigma = V\int_t\int l\Phi_t d\sigma = 0,$$

or that the product term vanishes in the expression for the kinetic energy of the fluid.

This result could have been obtained by noting that the integral $\int\int \Phi_t \frac{\partial \Phi_a}{\partial n} d\sigma$ is proportional to the product UV. Then, because of the longitudinal symmetry of a body of revolution if V is replaced by $-V$ the kinetic energy of the fluid is unaltered and therefore the coefficient of UV must vanish.

Expression for the Kinetic Energy T

Substituting from Eqs. (9), (12) into Eq. (5), the kinetic energy of the fluid is given by:

$$\frac{2T}{\rho} = \left(\frac{4}{3}\pi k^3 \frac{A_1}{v\,kU} - 1\right) v\,U^2 + \left(-\frac{8}{3}\pi k^3 \frac{B_1}{v\,kV} - 1\right) v V^2 \quad (14)$$

or comparing term for term with Eq. (3):

$$\left.\begin{aligned} A &= \left(\frac{\frac{4}{3}\pi k^2}{v}\frac{A_1}{kU} - 1\right)v = k_a \cdot v \\ B &= \left(-\frac{\frac{8}{3}\pi k^3}{v}\frac{B_1}{kV} - 1\right)v = k_t \cdot v \end{aligned}\right\} \quad (15)$$

Therefore

$$T = k_a \cdot \frac{1}{2}MU^2 + k_t \cdot \frac{1}{2}MV^2$$

where M is the mass of fluid displaced by the body and

$$\left.\begin{aligned} k_a &= \frac{\frac{4}{3}\pi k^3}{v}\frac{A_1}{kU} - 1, \text{ the inertia coefficient for axial flow} \\ k_t &= -\frac{\frac{8}{3}\pi k^3}{v}\frac{B_1}{kV} - 1, \text{ the inertia coefficient for transverse flow.} \end{aligned}\right\} \quad (16)$$

These remarkably simple expressions for the coefficients of inertia k_a, k_t, have already been obtained by C. Ferrari[3] by a method based on a consideration of the sink-source and doublet distributions along the axis of symmetry of the moving body in conjunction with Munk's theorem on sinks and sources.[4]

Conclusion

The results of this note, contained in Eq. (16), have been obtained without the necessity of introducing extraneous features to the flow, such as sinks and sources inside the moving body. It is to be further noted that rotational motion was not included. The reason for excluding this type of motion is suggested by the choices necessary for the arbitrary function ψ_1 appearing in Eq. (4). Thus, for axial flow ψ_1 was taken equal to Ux and for transverse flow equal to Vy. It is known that Ux and Vy are the velocity potentials of the rectilinear flows which must be superposed on the fluid and moving body in order to render the latter stationary. However, the rotational flow which must be superposed on the fluid and a rotating body, in order to fix the body in the fluid, does not possess a velocity potential and it therefore appears impossible to treat this type of motion in a manner analogous to that for rectilinear motion.

[3] Carlo Ferrari, *Sul campo aerodinamico attorno ad un solido siluriforme*, Memorie della R. Accademia delle Scienze di Torino, Serie II, vol. LXVII, N. 4, 1932.

[4] Carl Kaplan, *Potential Flow about Elongated Bodies of Revolution*, T. R. No. 516, N.A.C.A., 1935.

Errata

The following corrected mathematical expressions correct errors inadvertently made in the printing of Mr. Homer Stewart's paper on *"Tapered Beam Column Analysis for Uniformly Distributed Loads"*, on page 365 of the August 1936 issue.

$$J_{m+\frac{1}{2}}(z) = \sqrt{2/\pi}\,(-1)^m z^{m+\frac{1}{2}}\left(\frac{1}{z}\frac{d}{dz}\right)^m\left(\frac{\sin z}{z}\right)$$

$$J_{-m-\frac{1}{2}}(z) = \sqrt{2/\pi}\;z^{m+\frac{1}{2}}\left(\frac{1}{z}\frac{d}{dz}\right)^m\left(\frac{\cos z}{z}\right)$$

and also

$$Ci\,(u) = .577215 \log_e u - \frac{u^2}{2.2!} + \frac{u^4}{4.4!}$$

Airplane Tracks in the Surface of Stratus Clouds

IRVING LANGMUIR, *General Electric Company*

ALEXANDER FORBES, *Harvard Medical School*

(Received July 27, 1936)

CLOUD-FORMS differ greatly in stability, according to their type. Cumulus clouds are characterized by turbulence, whereas stratus clouds are, by contrast, stable and relatively static. The following is a description of a series of observations in which the stability of stratus clouds was shown by the persistence of tracks made in them by airplanes.

The first observation of the series was as follows:—

On October 21, 1933, at about 5 p.m. one of the authors (Langmuir) was flying at an altitude of 2,000 feet in an open Waco biplane about 6 miles southwest of Saratoga Springs, N. Y., and noticed that clouds began to form overhead rather quickly. The day had been humid and hazy but almost cloudless. The delicate marking of the clouds that were forming resembled those of cirrus clouds and suggested that they were at great height. But their rapid apparent motion indicated a much lower altitude, so it was decided to climb to their level. The clouds proved to be at a height of 6000 feet and by the time they were reached they constituted a continuous stratus cloud, covering an area of several square miles and having a thickness of about 500 feet. The upper surface, which was exceptionally clearly defined, was gently undulating, forming a series of regular parallel waves about 1500 feet apart, the valleys being perhaps 200 feet lower than the intervening ridges.

The upper surface was so nearly like a great snow field that the plane was flown across the waves, in a westerly direction, following the surface up to the ridges and down into the valleys. The sun was so low in the west that it was hidden behind the next ridge while the plane was in the valley. The upper surface was sharply defined within a foot or two so that it was frequently possible to fly the plane with the landing gear in the cloud while the rest of the plane was above it.

In some cases the plane was flown towards the west at such a level that only half the sun's disk was visible above the next ridge. It was then seen that at a height of two or three feet above the surface of the cloud there was sharp temperature discontinuity rendered visible by the "heat waves" caused by the irregular refraction of the sun's rays by the admixture of air masses of different temperatures.

This temperature difference could be felt very distinctly when the plane was flown alternately just above or just below the upper surface of the cloud, the air above the cloud being several degrees warmer than that in the cloud. (Usually just the reverse temperature difference is experienced in flying into the upper part of a cumulus cloud.) The upper surface of the cloud thus formed the boundary between an underlying layer of moist cool air and an overlying layer of dry warm air with relatively little difference in horizontal velocity between these layers.

After flying to the western limit of this stratus cloud, the plane was turned back towards the east and it was then noticed that the track of the plane could be seen for a distance of about two miles in the upper surface of the cloud. For about 20 minutes (until the sun had set) various manoeuvers were carried out to observe these tracks. The track consisted of a groove cut in the upper surface having a width about equal to the span of the wings and a depth which gradually increased with time until it became approximately equal to the width of the groove. This track or groove had approximately vertical sides and at the bottom of the groove was a narrow and deeper groove evidently caused by the slip-stream from the propeller. The track remained clearly visible for about two to three minutes, finally disappearing by gradually filling up and becoming indefinite in cross section. In some cases before complete disappearance, the track appeared as a ridge on the surface of the cloud instead of a depression.

The apparent cause of the track left by the airplane in the upper surface of the cloud is that the weight of the plane, which must be borne by the air through which it passes, gives to the air along the track a downward component of velocity. This causes the warm dry air which lies just above the cloud to be forced down into the cloud. Because of the difference in density of the air in this track and the surrounding colder air of the cloud, the downward motion is gradually dissipated and is followed by a swinging-back of the warm dry air and corresponding inflow of the cool moist air of the cloud. This oscillation could account for a ridge appearing before complete disappearance of the track.

The description of this observation led the other author to repeat it on several occasions, and in some instances to obtain photographic records of the effect.

The first successful attempt was on January 6, 1934, when stratus clouds offered a fairly sharply defined upper surface at 6000 feet above sea level near Boston. A distinct track was made in this surface and photographed from the plane within the next minute. The track was visible in the picture, but indistinct.

A better record was made on January 14, 1934. The upper surface of the clouds over Brockton, Massachusetts, in the late afternoon, was about 10,000 feet above sea level. Two or three successive tracks were made and photographed (see Fig. 1, A and B). The chief difficulty encountered at this altitude was that of climbing quickly enough after making the track to obtain a good position for photography.

The most successful photograph (Fig. 1, C) was taken on April 9, 1935, early in the afternoon, over the west end of Lake Erie at an altitude of about 4000 or 5000 feet.

On three other occasions tracks as sharply defined as that in Fig. 1, C, or even more so, were observed when no camera was available for photography. Probably the best example was on June 11, 1935, about 8:45 a.m., near New London, Connecticut, at an altitude of about 4000 feet. There was a thin, flat sheet of cloud and the plane was flown in its upper surface. On looking back from above, a few seconds later, a sharply defined furrow was seen, which looked as if it extended downward through the entire cloud layer, so that the ground below could be seen through it. More striking still was the elevation of the surface of the cloud layer at the left edge of the furrow. The same effect can be seen in Fig. 1, C, where the right edge appears raised. (This was the left edge of the track as made.) This is undoubtedly due to the rotary effect of the propeller on the slip-stream.

On four occasions attempts were made to see how long these tracks would remain visible. This was done in the case of the cloud just described (June 11, 1935). By circling over it, the track was kept in view as continuously as possible. For nearly two minutes it appeared almost as distinct as when first seen. At the end of two minutes it already appeared less distinct.

On June 5, 1935, between 4 and 5 p.m., fairly well-defined flat-topped clouds were found at about 2500 feet near Boston. Two visible tracks were made in these. One appeared distinct a half-minute after it was made, but was then lost sight of in circling; when next the plane was brought in line with its course, about 1¾ minutes after it was made, it could not be clearly distinguished from adjacent natural furrows. Evidently this cloud was of a less stable type than the preceding one.

Two clouds, both fairly stable, but differing greatly from each other, were observed on September 27, 1935.

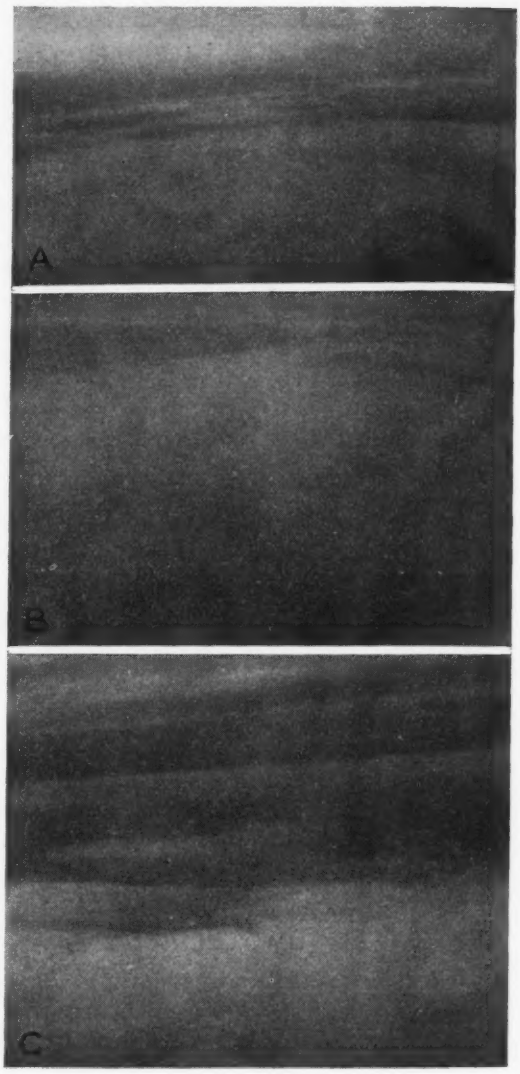

FIG. 1

A. January 14, 1934. Altitude, 10,000 feet. Track seen in profile of cloud surface near center of picture.

B. Same cloud surface as A. Track is visible approaching observer from middle of picture to foreground, where it shows as a dark wide band.

C. April 9, 1935. Clouds over Lake Erie. Track first appears cutting profile of cloud surface, left center; again cutting inner cloud mass and approaching observer in foreground of picture.

The plane was then equipped with pontoons for water flying. In the middle of the afternoon three low fog banks of small extent were seen over the water between Montauk Point and Block Island. One of these, three or four miles southeast of Point Judith, was examined. From one side it appeared flat and continuous, with a well-defined surface; from above it was seen to be broken into patches, the sea being visible through the gaps. The top of the cloud was about 150 feet above the water. A very sharply defined track was made

in this. It showed little change for more than a minute. When the plane was next in a good position for observation, two minutes after the track was made, it could no longer be seen.

About 15 minutes later, off Sakonnet Point, a long cylindrical cloud, its shape suggesting a roll of French bread, was found about 900 feet above the sea, its long axis being northeast and southwest. A track was made longitudinally in its supper surface. When first seen, looking back, about a half a minute later, the groove, sharply defined, was seen to be well to the northwest side of the highest point. It was kept in view till about 1½ minutes after it was made, when it was still further over on the northwest side of the cloud. At 2 minutes it could no longer be distinguished from irregularities of the cloud surface. Evidently this cloud was rotating fairly rapidly about its long axis.

On several occasions attempts were made to cut visible tracks through the tops of rounded cumulus clouds. By the time the plane could be manoeuvered into position for looking back, the tracks had become indistinct or had disappeared. This observation agrees with other evidence of turbulence in cumulus clouds.

On one occasion a visible track was made in the under surface of a cloud. One of us was flying south from Berlin, N. H., through Pinkham Notch, east of Mt. Washington. A flat layer of cloud hid the summit of the mountain, and when attaining an altitude of 6000 feet the plane was found to be in the cloud, although the ground was still visible. The under surface of the cloud was not sharply defined. No attempt was made to observe the track by looking back from the plane, but an observer on the ground reported that a track could be seen extending back from the plane for a long distance.

It may be concluded from a comparison of these observations that a sharply defined upper surface of a stratus cloud, correlated with inversion of temperature, presents a condition of great stability, and that in the case of stratus clouds the more sharply defined the surface, the greater is the stability

Book Reviews

Die Flugzeugfuehrer, by DIPL.-ING. OTTO R. THOMSEN; E. S. Mittler & Son, Berlin, 1936; 125 pages, ill., RM. 2.00.

This book on the training of recruits for the air force is aimed at facilitating this training, theoretically, as much as possible.

In a popular way is covers the entire ground of what an airplane pilot ought to know about airplanes, ground organization, aerodynamics, flying in general and flight manoeuvers. It emphasizes the position of responsibility of, and the necessary discipline for a pilot.

Die Fliegerschuetz, by MAJOR W. V. CORNBERG; E. S. Mittler & Son, Berlin, 1936; 62 pages, ill., RM. 1.30.

This book, on the training of the airplane machine gunner, goes into the details of his training as regards navigation, map making, radio-operation, knowledge of the machine gun and all its parts, meterology and weather maps.

Books Received

Birdflight as the Basis of Aviation, by OTTO LILIENTHAL; Longman's, Green and Co., London, England, 1911; 142 pages, ill.

Mr. Griffith Brewer some years ago secured a number of copies of this book which describes Otto Lilienthal's scientific experiments with flat and curved surfaces. It was first published in Berlin in 1889. After Otto Lilienthal's death, his brother Gustav added a biographical introduction and an account of the gliding experiments which are now classics of aviation history. The Institute appreciates Mr. Brewer's gift to its library.

L'Aviazione Civile; by ALFONSO PIROZZI; Angelo Signorelli. Rome, 1936; 211 pages.

Mitteilungsblatt Nr. 4, (der Internationalen Studienkommission für den motorlosen Flug; Darmstadt, August. 1935. 104 pages.

Elastic Stability of Plane Frameworks

W. PRAGER, *Istanbul University, Turkey*

(Received July 28, 1936)

THE method of investigating the elastic stability of plane frameworks presented in this paper departs from the idea that any member of a plane framework may be regarded as a bar elastically supported and elastically clamped at both ends. A constantly used equation permitting the determination of the critical compressive load of such a bar will therefore presently be established.

The following notations are used:

l = length of the bar,

EI = flexural rigidity of the bar for bending in the plane of the framework of which it is a member,

$l' = l/EI$

N = actual compressive load of the bar.

The stability-coefficient of the bar will be designated by s so that sN will be the critical compressive load of the bar. Let the deflections of the bar be referred to a system of rectangular axes taken in such a manner that the axis of x coincides with the center line of the undeformed bar, the abscissae of the two end points of the bar being 0 and l. The bar exposed to the critical load sN will take deflections $y(x)$ satisfying the differential equation

$$y^{IV} + p^2 y'' = 0 \quad \text{where} \quad p^2 = sN/EI. \tag{1}$$

The general solution of this differential equation can be written in the form:

$$y = a + bpx + c\cos px + d\sin px, \tag{2}$$

in which the constants a, b, c, d must be adjusted to the conditions at the ends of the bar.

Now by the condition of elastic encastrement at the end $x = 0$ the bending moment $M(0)$ at this endpoint is proportional with the slope $y'(0)$ of the deformed center line there, the coefficient of proportionality being a measure of the rigidity of encastrement. The encastrement coefficients used in this paper are defined as follows:

$$e(0) = -\frac{M(0)l'}{y'(0)} \quad , \quad e(l) = -\frac{M(l)l'}{y'(l)} \, . \tag{3}$$

Similarly by the condition of elastic supporting at the end $x = 0$ the shearing force $S(0)$ at this end is proportional with the deflection $y(0)$ there, the coefficient of proportionality being a measure of the rigidity of support. The supporting coefficients used in this paper are defined as follows:

$$f(0) = -\frac{S(0)l^2 l'}{y(0)} \quad , \quad f(l) = -\frac{S(l)l^2 l'}{y(l)} \, . \tag{4}$$

To specify the end conditions of an elastically clamped and elastically supported bar it is sufficient to give the numerical values of the coefficients e and f for both ends of the bar. The following cases are of particular interest: For a hinged end ($y = 0, M = 0$) the coefficients assume the values $e = 0, f = \infty$, for an end rigidly built in ($y = 0, y' = 0$) the values of the coefficients are $e = \infty, f = \infty$ and for a free end ($M = 0, S = 0$) they are $e = 0, f = 0$.

If in the relations defining the encastrement and supporting coefficients the bending moments and shearing forces are expressed in terms of the derivatives of y ($M = -EIy''$, $S = -EIy''' - sNy'$), and the expressions of y and its derivatives according to Eq. (2) are introduced, four equations linear and homogenous in the integration constants a, b, c, d are obtained. The condition that these equations admit a system of solutions a, b, c, d, which do not all vanish, gives the following condition for the buckling of the bar:

$$\begin{aligned} &e(0)f(0)\left\{e(l)f(l)A(\lambda) - e(l)B(\lambda) - f(l)C(\lambda) + D(\lambda)\right\} \\ &+ e(0)\left\{e(l)f(l)B(\lambda) - f(l)D(\lambda)\right\} \\ &+ f(0)\left\{e(l)f(l)C(\lambda) - e(l)D(\lambda) + f(l)B(\lambda) - E(\lambda)\right\} \\ &+ e(l)f(l)D(\lambda) + f(l)\,E(\lambda) = 0, \end{aligned} \tag{5}$$

where $\lambda = pl$ and

$$\begin{aligned} A(\lambda) &= \frac{1}{\lambda^4}(2\cos\lambda + \lambda\sin\lambda - 2), \\ B(\lambda) &= \frac{1}{\lambda}\sin\lambda, \\ C(\lambda) &= \frac{1}{\lambda^3}(\lambda\cos\lambda - \sin\lambda), \\ D(\lambda) &= \cos\lambda, \\ E(\lambda) &= \lambda\sin\lambda. \end{aligned} \tag{6}$$

A table of numerical values of the functions A, B, C, D, E useful for computations is given as Table I.

Eq. (5) is the basic equation of the method presented in this paper. It contains as border cases the buckling conditions for the well-known four elementary cases of the hinged-hinged, hinged-clamped, clamped-free and clamped-clamped bar. For the bar hinged at both ends for instance one has $e(0) = 0, e(l) = 0$.

TABLE I

λ	A (λ)	B (λ)	C (λ)	D (λ)	E (λ)
0.0.....	—0.08333	+1.00000	—0.33333	+1.00000	0.00000
0.2.....	—0.08311	0.99335	—0.33200	0.98007	+0.03973
0.4.....	—0.08245	0.97355	—0.32803	0.92106	0.15577
0.6.....	—0.08135	0.94107	—0.32149	0.82534	0.33879
0.8.....	—0.07984	0.89669	—0.31248	0.69671	0.57389
1.0.....	—0.07792	0.84147	—0.30117	0.54030	0.84147
1.2.....	—0.07564	0.77670	—0.28774	0.36236	1.11845
1.4.....	—0.07300	0.70389	—0.27241	+0.16997	1.37963
1.6.....	—0.07005	0.62473	—0.25544	—0.02920	1.59932
1.8.....	—0.06682	0.54103	—0.23711	—0.22720	1.75293
2.0.....	—0.06336	0.45465	—0.21770	—0.41615	1.81859
2.2.....	—0.05969	0.36750	—0.19752	—0.58850	1.77869
2.4.....	—0.05587	0.28144	—0.17688	—0.73739	1.62111
2.6.....	—0.05194	0.19827	—0.15609	—0.85689	1.34030
2.8.....	—0.04794	0.11964	—0.13544	—0.94222	0.93797
3.0.....	—0.04391	+0.04704	—0.11523	—0.98999	+0.42336
π.....	—0.04106	0.00000	—0.10132	—1.00000	0.00000
3.2.....	—0.03990	—0.01824	—0.09571	—0.99829	—0.18680
3.4.....	—0.03594	—0.07516	—0.07713	—0.96680	—0.86884
3.6.....	—0.03207	—0.12292	—0.05971	—0.89676	—1.59307
3.8.....	—0.02833	—0.16101	—0.04363	—0.79097	—2.32506
4.0.....	—0.02474	—0.18920	—0.02903	—0.65364	—3.02721
4.2.....	—0.02134	—0.20752	—0.01603	—0.49026	—3.66062
4.4.....	—0.01815	—0.21627	—0.00470	—0.30723	—4.18705
4.6.....	—0.01518	—0.21602	+0.00491	—0.11215	—4.57098
4.8.....	—0.01246	—0.20753	0.01281	+0.08750	—4.78159
5.0.....	—0.00996	—0.19179	0.01902	0.28366	—4.79462
5.2.....	—0.00774	—0.16989	0.02361	0.46852	—4.59397
5.4.....	—0.00577	—0.14311	0.02667	0.63469	—4.17293
5.6.....	—0.00405	—0.11273	0.02833	0.77557	—3.53509
5.8.....	—0.00254	—0.08010	0.02870	0.88552	—2.69469
6.0.....	—0.00136	—0.04657	0.02796	0.96017	—1.67649
6.2.....	—0.00035	—0.01340	0.02627	0.99654	—0.51515
2 π.....	0.00000	0.00000	+0.02533	+1.00000	0.00000

$f(0) = \infty$, $f(l) = \infty$. Consequently only the term $f(0)\, f(l)\, B(\lambda)$ of the basic Eq. (5) has to be retained, as all other terms vanish beside it. The buckling condition thus obtained is $B(\lambda) = 0$ and admits as the smallest positive root $\lambda = \pi$. By the definition of λ this gives the well-known value.

$$_{s}N = \pi^2 \frac{EI}{l^2}$$

for the critical compressive load of the bar hinged at both ends.

Eq. (5) gives the buckling condition of an elastically clamped and elastically supported bar provided that the critical stress σ_{cr} corresponding to the critical compressive load is within the proportional range. According to a suggestion made by F. Engesser (Schweizer Bauzeitung, vol. 25, p. 172, (1895)) buckling conditions

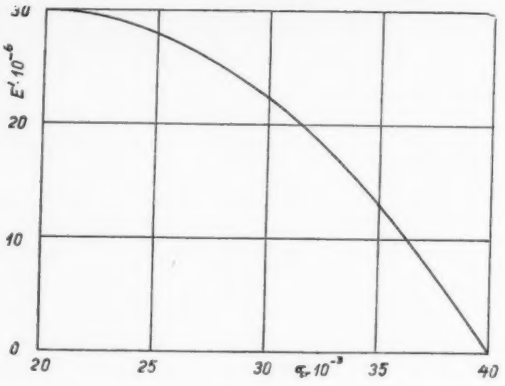

FIG. 1

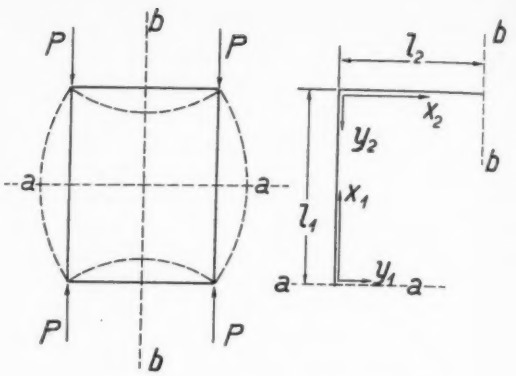

FIG. 2 FIG. 3

valuable within the proportional range may be applied also in cases where the critical stress is beyond the proportional limit if only the modulus of elasticity E is replaced by the reduced modulus E'. For instance, let the Johnson-formula for structural steel be adopted:

$$\sigma_{cr} = 40{,}000 \left\{ 1 - \frac{1}{30{,}000} \left(\frac{l}{r} \right)^2 \right\} \text{ lbs. per sq.in.}$$

This formula gives $\sigma_{cr} = 40{,}000$ lbs. per sq.in. for very short bars and is valuable up to a slenderness ratio $l/r = 122.5$. By eliminating the slenderness ratio l/r between this formula and the relation ($\sigma_{cr} = \pi^2 E' (r/l)^2$) defining the reduced modulus of elasticity the following relation between critical stress and reduced modulus of elasticity is obtained:

$$E' = \frac{30{,}000}{\pi^2} \sigma_{cr} \left\{ 1 - \frac{\sigma_{cr}}{40{,}000} \right\} \text{ lbs. per sq.in.} \qquad (7)$$

This relation represented in Fig. 1 is valuable only for critical stresses between 20,000 and 40,000 lbs. per sq.in. For critical stresses below 20,000 lbs. per sq.in. one has $E' = E = 30 \cdot 10^6$ lbs. per sq.in.

Eq. (7) being derived from the Johnson formula is, like this formula, in principle only applicable to the hinged-hinged bar. Following Engesser's suggestion it may however also be assumed as valuable for any end conditions of the bar. In this case a first computation has to be made using the value $E = 30 \cdot 10^6$ lbs. per sq.in. If the critical stress σ_{cr} corresponding to the critical compressive load found by this computation is above 20,000 lbs. per sq.in. the computation has to be repeated using the reduced modulus E' corresponding to the critical stress furnished by the first computation. In this way the computation has to be repeated until the reduced modulus employed in a computation coincides with, or differs only slightly from, the reduced modulus corresponding to the critical stress furnished by this computation. Generally this method converges very rapidly. An example will be given later on.

So far only a single bar elastically clamped and elastically supported has been considered. Now consider a plane structure composed of bars which are freely pinned or stiffly joined together. If one of the ends of a bar which is a member of such a structure is considered both coefficients e and f for this end may be immediately given, or only one or even none of them. Fortunately the latter case is very rare, so that it can be excluded from the considerations which are thus essentially simplified.

Consider for instance two bars of length l_1 and l_2 respectively, stiffly joined at a rigid support, the axes of the bars being on the same straight line. The support being rigid the supporting coefficients of the bar ends left and right of the support are both infinite: $f_1 = \infty$, $f_2 = \infty$. Whereas these supporting coefficients can be immediately given the encastrement coefficients, e_1 and e_2 of the bar ends to the left and right of the support are not known. Their ratio however can easily be determined. Indeed, the bending moments M_1 and M_2 as well as the slopes y'_1 and y'_2 of the bending line at both sides of the support being the same, by the definition of the encastrement coefficients (3) one has

$$e_1/e_2 = l'_1/l'_2.$$

Now consider a continuous beam on three supports (Fig. 2). At the end supports

$$e_1(0) = 0, f_1(0) = \infty, e_2(l_2) = 0, f_2(l_2) = \infty.$$

and at the mean support we have $f_1(l_1) = f_2(0) = \infty$ and

$$e_1(l_1)/e_2(0) = l'_1/l'_2. \qquad (8)$$

Writing the basic Eq. (5) for the first bar one has to retain only the terms containing the infinite product $f_1(0)\, f_1(l_1)$ and not containing the vanishing factor $e_1(0)$. The basic equation thus takes the form

$$e_1(l_1)\, C(\lambda_1) + B(\lambda_1) = 0$$

Similarly the basic equation for the second bar is

$$-e_2(0)\, C(\lambda_2) + B(\lambda_2) = 0.$$

Introducing the expressions of $e_1(l_1)$ and $e_2(0)$ following from these equations in Eq. (8) the following buckling condition is obtained:

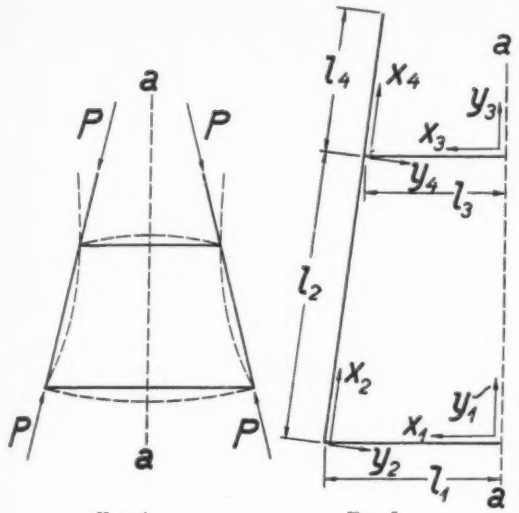

FIG. 4

FIG. 5

$$\frac{1}{l_1'}\frac{B(\lambda_1)}{C(\lambda_1)} = -\frac{1}{l_2'}\frac{B(\lambda_2)}{C(\lambda_2)}. \tag{9}$$

If, for instance, the flexural rigidity EI as well as the actual compressive load N are the same for the two bars, the ratio of their lengths being $l_1/l_2 = 2$, we have by the definition of λ:

$$\lambda_1 = 2\,\lambda_2,$$

and the buckling condition can be written in the form:

$$B(2\lambda_2)/C(2\lambda_2) = -2B(\lambda_2)/C(\lambda_2).$$

The functions B and C being tabulated, the smallest positive root of this equation can easily be determined, it has the value $\lambda_2 = 1.92$. By the definition of λ this gives as stability coefficient of the beam:

$$s = \left(\frac{\lambda_2}{l_2}\right)^2 \frac{EI}{N} = 3.70\,\frac{EI}{Nl_2^2}.$$

Applied to continuous beams this method is essentially the same as that given by H. Zimmermann (Knickfestigkeit der Stabverbindungen, Berlin 1925), whose "Spannziffern" corresponds to the encastrement coefficients. Owing to the introduction of the supporting coefficients this method permits however the treatment of problems which can not be treated by the Zimmermann method. The exact scope of both methods has been investigated in a paper which will be published in the Russian Journal of Applied Mathematics and Mechanics.

As a second example the critical values of the forces P compressing the vertical members of the rectangular frame of Fig. 2 will be determined. The deformation of the frame will be symmetrical about the lines *a-a* and *b-b*, so that the consideration of a fourth of the frame is sufficient (Fig. 3). The symmetry conditions

$$y_1'(0) = 0,\ S_1(0) = 0,\ y_2'(l_2) = 0,\ S_2(l_2) = 0$$

give

$$e_1'(0) = \infty,\ f_1(0) = 0,\ e_2'(l_2) = \infty,\ f_2(l_2) = 0.$$

Further

$$y_1(l_1) = y_2(0) = 0$$

which gives

$$f_1(l_1) = f_2(0) = \infty$$

The bending moments $M_1(l_1)$ and $M_2(0)$ as well as the slopes $y'_1\ (l_1)$ and $y'_2\ (0)$ of the bending lines being the same we have again (see Eq. (8) to Eq. (9)).

$$e_1(l_1)\,/\,e_2(0) = l_1'\,/\,l_2'.$$

The basic Eq. (5) takes the following forms for the two bars

$$e_1(l_1)\,B(\lambda_1) - D(\lambda_1) = 0 \quad \text{and} \quad -e_2(0)\,B(\lambda_2) - D(\lambda_2) = 0.$$

Introducing the values of $e_1(l_1)$ and $e_2(0)$ following from these equations in relation (see Eq. (8) to (9)) one obtains

$$\frac{1}{l_1'}\frac{D(\lambda_1)}{B(\lambda_1)} = -\frac{1}{l_2'}\frac{D(\lambda_2)}{B(\lambda_2)} \tag{10}$$

Now the actual compressive load on the second bar is $N_2 = 0$, so that $\lambda_2 = 0$. Introducing the values $B\ (0) = 1$ and $D\ (0) = 1$ found in Table I in Eq. (10) one obtains the buckling condition

$$D(\lambda_1)\,/\,B(\lambda_1) = -\,l_1'\,/\,l_2'.$$

If, for instance, a square frame whose members have the same cross section is considered ($l_1 = l_2 = l$, $I_1 = I_2 = I$) the buckling condition becomes $D(\lambda_1) = -B\lambda_1)$. A simple inspection of Table I shows the smallest positive root of this equation to be about $\lambda_1 = 2.03$ which gives the stability coefficient

$$s = \frac{4.12}{l^2}\,\frac{EI}{P}.$$

As a third example the buckling condition of the frame shown in Fig. 4 is derived, supposing that the deformation is symmetrical about the line *a-a*. Owing to this symmetry our considerations can be confined to half of the frame (Fig. 5). The symmetry conditions.

$$y_1'(0) = 0,\ S_1(0) = 0,\ y_3'(0) = 0,\ S_3(0) = 0,$$

give

$$e_1(0) = \infty,\ f_1(0) = 0,\ e_3(0) = \infty,\ f_3(0) = 0.$$

Further

$$y_1(l_1) = y_2(0) = 0,\ y_2(l_2) = y_3(l_3) = y_4(0) = 0,$$

which gives

$$f_1(l_1) = f_2(0) = \infty,\ f_2(l_2) = f_3(l_3) = f_4(0) = 0$$

and at the free end $x_4 = l_4$ we have $M_4(l_4) = 0$, $S_4\ (l_4) = 0$, which gives

$$e_4(l_4) = 0,\ f_4(l_4) = 0.$$

At $x_1 = l_1$, $x_2 = 0$ we have again (see Eq. (8) to Eq. (9))

$$e_1(l_1)/e_2(0) = l'_1/l'_2.$$

At $x_2 = l_2$, $x_3 = l_3$, $x_4 = 0$ however the slopes of the bending lines of the three bars are the same ($y_2'(l_2) = y_3'(l_3) = y_4'(0)$), and between the bending moments there exists the equilibrium condition $M_2(l_2) + M_3(l_3) = M_4(0)$. From this relation follows

$$\frac{1}{l_2'} e_2(l_2) + \frac{1}{l_3'} e_3(l_3) = \frac{1}{l_4'} e_4(0). \tag{11}$$

For the first and third bar the basic Eq. (5) becomes

$$e_1(l_1) B(\lambda_1) - D(\lambda_1) = 0 \text{ and } e_3(l_3) B(\lambda_3) - D(\lambda_3) = 0.$$

The actual compressive loads on these bars being $N_1 = N_3 = 0$, one has $\lambda_1 = \lambda_3 = 0$. With $B(0) = D(0) = 1$ the above equations furnish the values

$$e_1(l_1) = e_3(l_3) = 1.$$

For the second bar the basic Eq. (5) takes the form

$$e_2(0)\, e_2(l_2)\, A(\lambda_2) - e_2(0)\, C(\lambda_2) + e_2(l_2)\, C(\lambda_2) + B(\lambda_2) = 0. \tag{12}$$

Now with the $e_1(l_1) = 1$ relation (see Eq. (8) to Eq. (9)) this gives $e_2(0) = l'_2/l'_1$. Inserting this value in Eq. (12)

$$e_2(l_2) = \frac{[C(\lambda_2)\, l'_2/l'_1] - B(\lambda_2)}{[A(\lambda_2)\, l'_2/l'_1] + C(\lambda_2)}$$

For the fourth bar finally the basic Eq. (5) gives

$$e_4(0) = E(\lambda_4)/D(\lambda_4).$$

Introducing the expressions of $e_2(l_2)$, $e_3(l_3)$, $e_4(0)$ in Eq. (11) the buckling condition of the frame is obtained as

$$\frac{1}{l'_1} \frac{[C(\lambda_2)\, l'_2/l'_1] - B(\lambda_2)}{[A(\lambda_2)\, l'_2/l'_1] + C(\lambda_2)} + \frac{1}{l'_3} = \frac{1}{l'_4} \frac{E(\lambda_4)}{D(\lambda_4)}.$$

To show how the buckling conditions obtained by this method are to be used in case the critical stress of one or several members of a structure is above the proportional limit, again consider the buckling condition, Eq. (9), of a continuous beam on three supports. Let the lengths l, the cross sections A and the inertia moments I be the same for the two bars and $N_1 = 2N_2$. Assuming for the first computation the same modulus of elasticity $E = 30 \cdot 10^6$ lbs. per sq.in. for both bars

$$\lambda_1/\lambda_2 = \sqrt{N_1/N_2} = \sqrt{2}$$

and the buckling condition, Eq. (9), becomes

$$B(\lambda_2\sqrt{2})/C(\lambda_2\sqrt{2}) = -B(\lambda_2)/C(\lambda_2).$$

The smallest positive root of this equation being $\lambda_2 = 2.47$ one has $\lambda_1 = \lambda_2\sqrt{2} = 3.50$. The critical stress of the first bar is

$$\sigma_{cr1} = \lambda_1^2 \frac{EI}{Al^2} = \lambda_1^2 E\left(\frac{r}{l}\right)^2 \quad \text{where } r = \sqrt{\frac{I}{A}} \text{ is the}$$

gyration radius of the beam. If this critical stress is below the proportional limit the assumption on which our computation is based is verified and the critical stress found will be the true critical stress. This will be the case if the slenderness ratio is above

$$\frac{l}{r} = \sqrt{\frac{3.50^2 \cdot 30 \cdot 10^6}{20{,}000}} = 135.$$

Now investigate the case where the slenderness ratio is below this value. Assuming, for instance, $l/r = 110$

$$\sigma_{cr1} = \lambda_1^2 E\left(\frac{r}{l}\right)^2 = \frac{3.50^2 \cdot 30 \cdot 10^6}{110^2} = 30{,}400 \text{ lbs. per sq. in.}$$

The compressive force on the second bar being half of that on the first the critical stress of the second bar is $\sigma_{cr2} = 0.5\ \sigma_{cr1} = 15{,}200$ lbs. per sq.in. The reduced moduli of elasticity corresponding to these stresses are $E'_1 = 21.9 \cdot 10^6$ and $E'_2 = 30 \cdot 10^6$ lbs. per sq.in. The second computation has therefore to be made inserting the values $l'_1/l'_2 = E'_2/E'_1 = 1.37$ and

$$\lambda_1/\lambda_2 = \sqrt{E'_2 N_1/E'_1 N_2} = 1.66$$

in the buckling condition, Eq. (9), which becomes

$$B(1.66\lambda_2)/C(1.66\lambda_2) = -1.37\, B(\lambda_2)/C(\lambda_2).$$

The smallest positive root of this equation is $\lambda_2 = 2.21$ which gives $\lambda_1 = 1.66\ \lambda_2 = 3.67$. The critical stresses corresponding to these values are

$$\sigma_{cr1} = \lambda_1^2 E'_1 \left(\frac{r}{l}\right)^2 = \frac{3.67^2 \cdot 21.9 \cdot 10^6}{110^2} = 24{,}300 \text{ lbs. per sq. in.}$$

and $\sigma_{cr2} = 0.5\ \sigma_{cr1} = 12{,}150$ lbs. per sq.in. To these stresses correspond the reduced moduli $E' = 28.6 \cdot 10^6$ and $E'_2 = 30 \cdot 10^6$ lbs. per sq.in. To accelerate the convergence repeat the computation with the value $E'_1 = 25.25 \cdot 10^6$ lbs. per sq.in. which is the means of the two values $21.9 \cdot 10^6$ and $28.6 \cdot 10^6$ obtained so far. Using again $E'_2 = 30 \cdot 10^6$ lbs. per sq.in. we have

$$l'_1/l'_2 = E'_2/E'_1 = 1.19 \text{ and}$$

$$\lambda_1/\lambda_2 = \sqrt{E'_2 N_1/E'_1 N_2} = 1.54.$$

The buckling condition Eq. (9) now takes the form

$$B(1.54\lambda_2)/C(1.54\lambda_2) = -1.19\, B(\lambda_2)/C(\lambda_2).$$

The smallest positive root $\lambda_2 = 2.33$ of this equation gives $\lambda_1 = 1.54\ \lambda_2 = 3.59$, and the critical stresses are

$$\sigma_{cr1} = \lambda_1^2 E'_1 \left(\frac{r}{l}\right)^2 = \frac{3.59^2 \cdot 25.25 \cdot 10^6}{110^2} = 26{,}900 \text{ lbs. per sq.in.}$$

and $\sigma_{cr2} = 0.5\ \sigma_{cr1} = 13{,}450$ lbs. per sq.in. The corresponding reduced moduli are $E'_1 = 26.4 \cdot 10^6$ and $E'_2 = 30 \cdot 10^6$ lbs. per sq.in. As these moduli are sufficiently near those employed in the last computation the critical stresses found by this computation can be considered as the true critical stresses. They are below the stresses which have been obtained in the first computation where perfect elasticity has been assumed.

Lateral Control Design

ARTHUR G. B. METCALF, *Boston University*

(Received August 10, 1936)

THE aerodynamic design of the lateral control in an airplane offers a problem which is handled by the airplane designer in many ways. These range all the way from the satisfying of wind tunnel criteria, necessarily crude because of model restraint, to the use of traditional design constants; the latter being the more usual approach. In general, it may be said that ailerons are employed, but not designed, to provide rolling control throughout the useful range of angle of attack.

The continued existence of this situation depends upon the fortunate circumstances that anything which looks like an aileron system is perfectly satisfactory at cruising speeds and that at high angles of attack, the experienced pilot, by the use of rudder, will mask any shortcoming of the aileron control by taking advantage of the large rolling moments due to yawing.

It is the purpose of this paper to discuss the aileron design problem and to state the case for ailerons designed to yield only a pure rolling moment.

The Ailerons

Any discussion of aileron effectiveness must consider, in addition to the usual rolling moment, the yawing moment produced by the ailerons, and further, the stiffness in yaw or the "static" directional stability of the airplane on which they are to be used. Aileron rolling moment criteria based upon rolling moment alone are of little, if any significance as applied to conventional installations. Expressed in another way the design of the ailerons is closely identified with the overall design of the airplane and cannot be considered apart from it, when conventional ailerons, which produce yawing moment as well as rolling moment, are used.

Using the standard symbolic designation [1, 2] the total aerodynamic rolling moment, L, with respect to body axes, may be expressed as:

$$L = L_A + pL_p + rL_r + vL_v$$

where the first right hand term, L_A, equals $C_l bSq$ or the rolling moment due to aileron displacement, and is what usually receives the most attention in discussions of aileron effectiveness, since the remaining terms do not appear in the usual tests with the model fixed in the tunnel.

Because of this, one is unable to say from such tests whether aileron control is adequate or not, or even, in many cases, if one aileron design is better than another.

There seems to be no easy way of avoiding this difficulty. The calculation of the controlled motion of the airplane using the dynamical equations of motion seems to offer the most promise. Unfortunately, this type of calculation is, in general, one which airplane designers do not commonly use. It has the advantage, however, of taking into account all operative factors.

The second of the terms on the right, pL_p, the damping of roll, always opposes the ailerons, and at all times carries a negative sign.

Adverse Yawing Moment

The conventional aileron having equal up and down motion is associated with the well-known "adverse" yawing moment. The effect of this is to make rL_r, the rolling moment due to angular velocity in yaw, and vL_v, the rolling moment due to angular displacement in yaw, negative, thus substantially diminishing the total rolling moment. Indeed, it is known that this effect may be large enough to cause the airplane to roll against the ailerons. It is, therefore, generally agreed that adverse yawing is never desirable.

Favorable Yawing Moment

In the past few years designers have been attracted to the idea of "favorable" aileron yawing moment. This insures that rL_r and vL_v will be of the same sign as the desired aileron rolling moment, substantially improving the control, and removing the possibility of reversal of control.

Although the opinion has been offered that under certain circumstances favorable aileron yawing moment might be an aid to safe flying, it is the writer's opinion that, in general, complete independence of the control, insofar as this can be attained, is desirable. This is recognized in military aircraft where high maneuverability is required. With respect to commercial and private types, the ability to turn the airplane using ailerons alone, under more or less restricted conditions, seems to be a rather questionable advantage when one considers that in the critical use of ailerons, namely, control at high angles of attack and control very near the ground, both in take off and landing, the pilot would

[1] E. B. Wilson, *Aeronautics*, John Wiley & Sons, Inc., 1920.
[2] E. P. Warner, *Airplane Design*, McGraw-Hill Book Company, 1927.

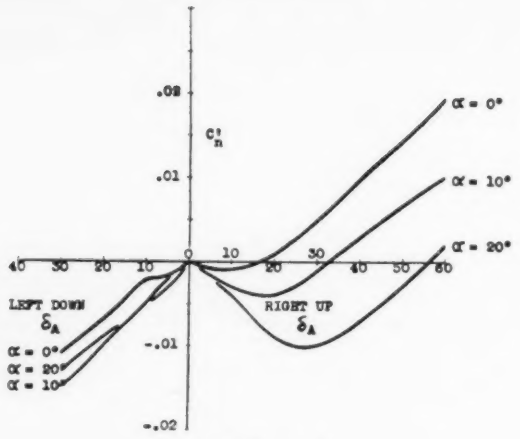

FIG. 1. No up-rig.

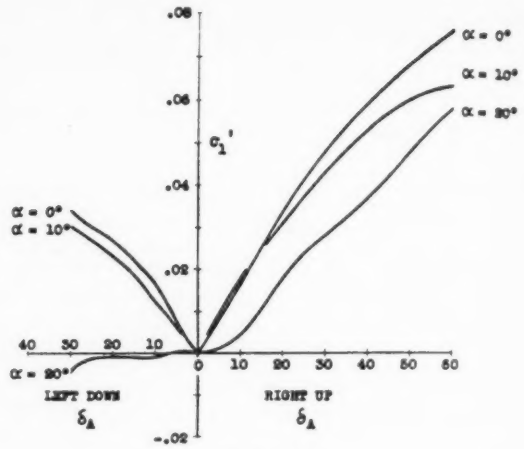

FIG. 2. No up-rig.

prefer to avoid turning the airplane, and an appreciable aileron yawing moment regardless of sign, can only serve to render the control more complicated.

Furthermore, with respect to single control turning, it may be mentioned that the rudder will always provide two large rolling moments, namely rL_r, and vL_v, the rolling moment due to angular velocity and angular displacement in yaw, respectively. Since these moments are unavoidable in any case, when the rudder is used, they might be usefully employed when it is desired to arrange the airplane for *rudder-only* turning. However, it must be accepted that a primary function of the *aileron* control is to enable the pilot to counteract these unavoidable rolling moments due to use of the rudder.

Viewed from this important standpoint, adverse aileron yawing moment would augment the undesirable rolling moments due to yaw, and favorable aileron yawing moment would reduce the maximum rudder power. Both conditions are undesirable and zero yaw ailerons seem to offer the solution.

It is important to note that it has been demonstrated[3] that in the case where the aileron rolling moment is sufficiently large to insure against a spiral divergence, that the resulting controlled oscillation is not improved, with respect to damping, by increased "favorable" yawing moment. Calculation of the controlled lateral motion seems to point to the desirability of arranging the aileron system so that it is free from yawing moment.

ZERO YAWING MOMENT

If the use of ailerons involved no yawing moment whatever, the designer should then be justified in expecting to realize wind tunnel rolling moment coefficients in flight, and a criterion based upon rolling moment would have meaning. For this reason, and further, because it renders useful a wealth of aileron wind tunnel data which is available, the zero yawing

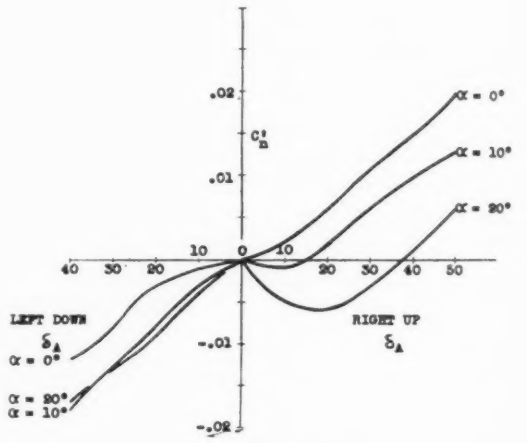

FIG. 3. 10° up-rig.

moment aileron is suggested as something worthy of the designer's consideration. Strictly speaking, even with such an aileron design, the system would not be entirely free of yawing moment, as there would still remain pN_p, the yawing moment due to angular velocity in roll, the value of which depends upon the magnitude of the angular velocity in roll. At the instant of application of the ailerons, in which, let us say, the purpose is to impress a large rolling moment upon the airplane, the value of pN_p is zero and has no effect upon the value of the instantaneously applied rolling moment. This, as recognized at once, is definitely not the case with ailerons yielding yawing moment, where such yawing moment at all times has a direct and important influence upon the total rolling moment impressed upon the airplane. It is, of course, not implied that pN_p is negligible in its effect upon the overall lateral motion of the airplane, but only that one is not concerned with it in a discussion dealing with aileron yawing moment.

Before considering the design aspects, it might be well to mention that aileron rolling and yawing moment data usually are referred to wind or tunnel axes, while

[3] O. C. Koppen, *Lateral Control at High Angles of Attack*, Journal Aero. Sciences. Vol. 2, No. 1, pp. 22–26, January, 1935.

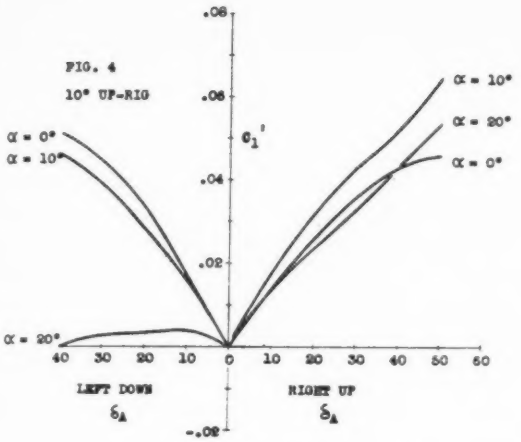

FIG. 4. 10° up-rig.

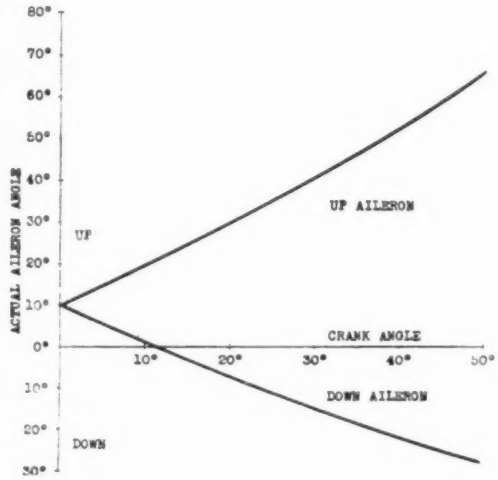

FIG. 5. Crank angle *vs.* actual aileron angle (relative to wing chord). 10° up-rig.

it is convenient to discuss control moments with respect to body axes. Because of this, zero yawing moment with respect to tunnel axes would mean a small positive moment with respect to body axes. The rolling moments would be likewise slightly modified. Since the labor involved in the transformation is relatively great as compared with the small differences obtained for angles less than 20°, the data used in this paper will be presented without applying this correction.

DESIGN

The procedure in the design of such an aileron system may now be treated. The wind tunnel data selected is for a Clark Y wing having a taper of 5:3 with short, wide ailerons tested by the N.A.C.A. It was felt that the tapered wing best represented current design practice and that these ailerons were desirable because of their large rolling moments as measured in the tunnel. The relatively large hinge moments identified with this type of aileron need not necessarily prove an insur-

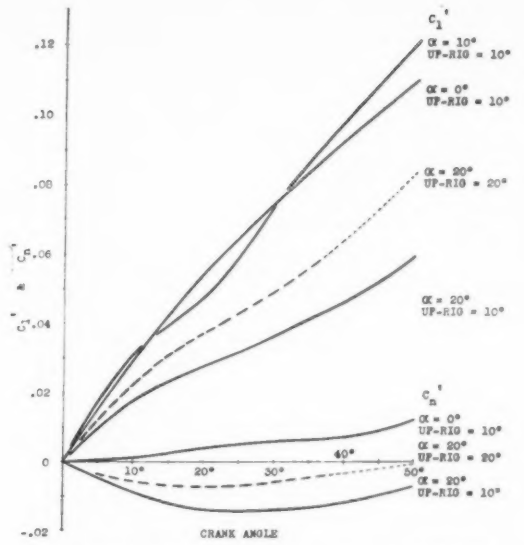

FIG. 6. Total rolling and yawing moment coefficients *vs.* crank angle.

mountable problem, if suitable aerodynamic balances designed to function at large angular displacements are used. N.A.C.A. Technical Note 449 contains the tabulated force test data as well as symbol conventions.

Figs. 1 and 2 are plots of yawing and rolling moment coefficient versus aileron displacement (relative to neutral position), with no up-rig, that is C'_n *vs.* δ_A and C'_l *vs.* δ_A respectively, referred to tunnel axes. It may be seen from Fig. 1 that at all values of the angle of attack (α), adverse yawing moments due to the "up" aileron are indicated. Figs. 3 and 4 are similar plots with the ailerons rigged up 10°, i. e. with both ailerons being initially set upward at an angle of 10° to their normal neutral position. Fig. 3 shows the effect of up-rig upon the up-aileron adverse yawing moment, where it is eliminated entirely at low angles of attack and much reduced at high angles. Later in this paper, a means of further reducing this yawing moment at high angles of attack will be suggested.

Fig. 5 represents a suggested aileron motion, that is, a plot of *actual* aileron angle *vs.* crank angle. The crank angle refers to any index of aileron motion where the two ailerons are interconnected and move with respect to the wing in an appropriate manner. Since the actual aileron angle is plotted, the angle of up-rig, 10°, appears as the aileron angle for both ailerons at the zero crank angle position. It will also be noted that the up-aileron motion is not linear but that the rate of change of aileron angle with respect to crank (or wheel) angle increases with wheel angle. This is desirable in a system such as that being discussed, where, in order to insure good lateral control at the stall, it is necessary to take advantage of the rolling moment associated with large angular displacement of the surfaces. In this case the maximum up-aileron angle is of the order of 60°. A linear control linkage

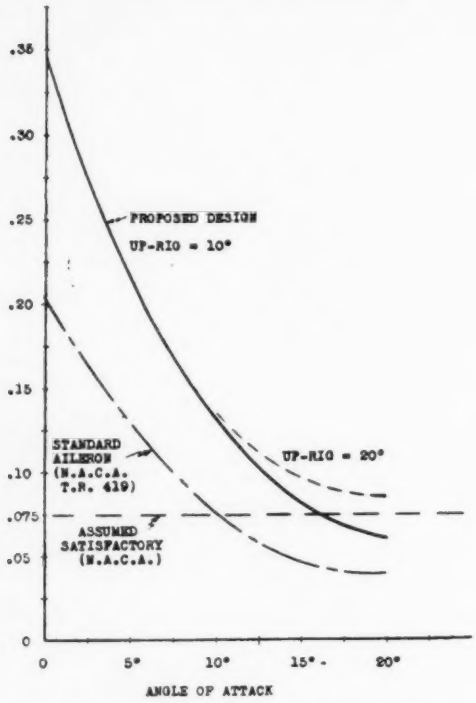

FIG. 7. Maximum rolling criterion *vs.* angle of attack.

providing these large angular displacements would give excessively large rolling moment coefficients for small control wheel movement, making for over-sensitive control at cruising speed. From the standpoint of ease of operation it is important to avoid this. An even greater curvature in the control motion variation than is indicated in Fig. 5 would probably be an improvement. A suitable linkage to provide such a motion represents no serious problem in mechanical design.

Fig. 6 is a plot of *total* rolling and yawing moment coefficient *vs.* crank angle, where the individual aileron moments are combined in the accepted manner. The values are appropriate for the linkage described by Fig. 5, with 10° up-rig. Dotted curves indicating the values corresponding to an angle of attack of 20° with an up-rig of 20° are included, since it is interesting to note the improvement in control in this region with the increased up-rig angle. For these curves the extreme upper values (shown lightly dotted) are extrapolated from the data available since ample justification exists for doing so.

The important features with respect to this set of curves are these:

(a) The yawing moments have values close to zero at both high and low angles of attack for all control settings. The values for angles of attack between $\alpha = 0$ and $\alpha = 20°$, within the usual flight range, would occupy intermediate positions somewhat nearer the $\alpha = 0°$ curve.

It is possible, of course, to make the yawing moment exactly zero for all control displacements by more careful adjustment of the up-rig and the motion. Such exactness, however, is probably unwarranted.

(b) An up-rig of 20°, for $\alpha = 20°$, for the same motion, substantially improves the rolling moment and further reduces the rather small adverse yawing moment which still persists at high angles of attack.

The control effectiveness may be best discussed with reference to Fig. 7, which is a plot of the well-known rolling criterion, R. C.[4] versus angle of attack. This criterion of aileron control is based upon maximum rolling moment alone, tacitly assuming that the airplane is restrained in one way or another from taking up angular displacement, or angular velocity, in yaw. Where such restraint is presumed to come from a timely and adequate use of the rudder, the aileron control is complicated unnecessarily, and it is quite possible that the rudder control may not be sufficiently powerful to realize the rolling moments measured in the wind tunnel, in which case the lateral control will fall short of the designer's expectations.

For the aileron design under consideration these difficulties are avoided and Fig. 7 may be taken as a plot of the measure of aileron effectiveness. The dashed horizontal line at R. C. = .075 represents the N.A.C.A. assumed minimum value of the rolling criterion for satisfactory control. The broken curve represents the values for ailerons accepted as standard, for purposes of comparison, having a chord of 25 per cent and equal up and down deflection of 25°. The solid curve refers to the proposed design where the upper branch (dotted) at high angles of attack indicates the effect of an up-rig of 20° for $\alpha = 20°$. For this curve, the values of the criterion are seen to be above the satisfactory level up to an angle of attack of about 16° for the 10° up-rig, and up to a very high angle of attack (over 20°) for the 20° up-rig. They are at all times substantially greater than the corresponding values for the standard ailerons, for which it must be remembered, the rolling criterion is a measure of lateral control only if the airplane is restrained in yaw. In general this would not be possible at high angles of attack with the average rudder so that the rolling criterion plotted for the standard aileron is potential rather than actual as is true with the proposed design for all engineering purposes.

The case for zero yaw ailerons may be summed up briefly as follows:

(1) Aileron control effectiveness may be predicted from wind tunnel tests or data already available. Large rolling moments may be obtained with no difficulty.

(2) The ailerons may be designed with no reference to the directional stiffness of the airplane upon which they are to be used.

[4] Fred E. Weick and Carl J. Wenzinger, *Wind-Tunnel Research Comparing Lateral Control Devices, Particularly at High Angles of Attack*, N.A.C.A. Report No. 419, 1932.

(3) The ailerons may be used to balance the unavoidable rolling moments due to a given rudder deflection without disturbing the equilibrium in yaw.

(4) Where good control is desired at large angles of attack, it would seem worthwhile to take advantage of the benefits to be derived from the 20° up-rig in this region. A suggested method would be to arrange the control system so that the angle of up-rig is a function of elevator angle, that is, causing the neutral aileron position to move upward to a maximum of 20°, say, as the control column moves backward.

(5) The effect of the up-rig upon the lift distribution across the span is such as to modify, in a beneficial manner, certain rotary derivatives which are important to the lateral stability of the airplane.

(6) From the standpoint of the stability of the controlled lateral motion which, after all, is the important consideration, the use of ailerons having zero yawing moment is indicated.

Book Review

Climatic Maps of North America, by CHARLES F. BROOKS, A. J. CONNOR and others; Blue Hill Meteorological Observatory, Harvard University, Cambridge, Massachusetts, 1936; $3.00.

This series of 26 large scale maps (folio form) will appear in the forthcoming Köppen-Geiger Handbuch der Klimatologie, Vol. II of which "The Climates of North America", by R. de C. Ward, C. F. Brooks, and A. J. Connor, will contain a critical discussion of what they disclose. The basic data for the maps were compiled by the weather services of the United States, Canada and Mexico. Data for the West Indies were based on ship reports collected by the Marine Division of the U. S. Weather Bureau and the Deutsche Seewarte. For Greenland the maps depend on Sverdrup, and for Central America on Sapper's studies.

Six maps give sea-level isotherms for January, March, May, July, September, and November and show the temperature variation over our continent as affected by the distribution of land, water and mountain barriers, with the effect of altitude eliminated. They bring out for the first time the striking warmth of the chinook-swept high plains of Wyoming and Montana, in contrast to the cold of North Dakota, which is in the path of frequent outbreaks of polar continental air masses in winter.

Maps of Actual Temperature Distribution for January and July are based on records going back from 25 to 93 years. They look much like topographic maps, especially in summer, when valleys are much warmer than the heights.

The Mean Annual Range of Temperature shows the difference between the average temperatures of the warmest and coldest months. Between the equable Pacific coast and the extremes of the interior immediately behind the coastal mountains, the contrast is most marked.

The Mean Annual Maximum and Minimum Temperature Maps are not unlike previous maps of this character but there has not been, heretofore, available the more significant average of the highest and average of the lowest temperatures each year for the period of man-made records.

The January and July maps of Sea Level Pressure indicate the prevailing trends of the winds, inward toward the continent in summer and outward in winter. The sub-polar low pressure belt is divided by the Yukon cold high in winter and virtually wiped out in the west by the cool north Pacific high in summer. The rudiments of a polar cap of high pressure are indicated both winter and summer.

The remaining twelve maps of the series include annual averages for rainfall and snowfall, maps of mean relative humidity for January and July, and maps of average cloudiness for the same months. A map of the annual number of thunderstorm days is of particular interest to aircraft operators who may have already noted the marked increase in frequency of thunderstorms in passing from Maine (10) to Florida (90). The scarcity of thunderstorms in the cool north is assisted by the blighting effect of cold coastal water north of Hatteras. The interior and south, being warm and muggy in summer, are favorable to thunderstorm development; so also are the southern Rockies and the east Gulf coast (high humidity). Western Haiti (100) is the most thundery area of all.

Some of us in aeronautics are so anxious about forecasting tomorrow's weather that our enthusiasm for a favorite prescription for this form of fortune telling may lead us to ignore the weather of yesterday. Climatology presents probabilities, as in these maps, and furnishes a rational historical background for any thinking about weather more than a few days ahead. Perhaps the sometimes accurate long range predictions by unorthodox methods owe their practical success to a probability factor of climatology. An almanac maker might predict with safety for January a severe freeze in Duluth, heavy rainfall in Seattle, deep snow at Lake Placid, and sunless days at Detroit.

While not strictly concerned with a notice of Dr. Brook's beautiful maps, this reviewer cannot resist the impulse to record the fact that Admiral D. W. Taylor, single handed, succeeded in forecasting the weather of Washington for a prolonged period with better success than the official meteorologists with their nation-wide system of observations. The Admiral's secret method was finally disclosed. Each day he wrote on a slip of paper a description of the weather as he saw it out of his window. He dated this paper for the next day and deposited it, together with ten cents, in a locked box. A colleague deposited a slip of paper bearing the official forecast for the next day, and also ten cents. The ten cents was important as establishing both an incentive for maintaining the experiment for a sufficiently long period of time, and also to ensure rigid and scrupulous comparison of actual weather with the two forecasts.

There is evidently a continuity in our weather, even though it appears to change in a fitful manner. Our day to day weather changes are like an irregular disturbance of low mean amplitude superimposed on a fundamental wave of long period and large amplitude. Climatology discloses the fundamental wave that governs life on this planet.

J. C. HUNSAKER.

The Helicopter: Propulsion and Torque

HAVILAND H. PLATT, *New York City*

(Received July 27, 1936)

Summary

THE only helicopter arrangement holding promise of useful performance is held to be that having a single rotor of large diameter. Propulsion by tilt of the feathering or flapping rotor closely approaches the ideal in that it requires no additional weight for propulsion and diverts no power from sustentation.

The fundamental attractiveness of the countervane principle has led to a theoretical and experimental investigation of its applicability to helicopter torque neutralization. A definite arrangement of vanes is required. The test results confirm theory in predicting satisfactory torque control with countervanes under all flight conditions. The ground effect is shown to be critical.

Introduction

Of the many problems which are encountered in the helicopter only three may be considered of a fundamental nature: 1. Sustentation; 2. Propulsion; and 3. Torque.

The question of sustentation has been so thoroughly investigated both theoretically and experimentally that it may be considered completely and satisfactorily answered.[1, 2] Very attractive lift per horsepower is thus found to be available, both statically and in translation, provided only the mechanical design permits of its advantageous utilization. For one reason or another all past helicopter arrangements have failed in this requirement. The examination in detail of these reasons is such a complex and extensive subject that it can not be compressed into the space allotted to this paper. Such an investigation has been made however and the conclusion drawn from it is that only one basic arrangement holds any substantial promise of attaining really useful performance.

The investigation here to be set forth, for the above reasons, deals exclusively with a generic design comprising a single lift screw of large diameter rotating about a generally vertical axis. The tests to be referred to were all made in the nine foot wind tunnel of the Daniel Guggenheim School of Aeronautics, New York University. The lift screw model was $52\frac{3}{16}$ inches in diameter with two flat blades of uniform section. The pitch was adjustable and the hub was constructed to provide completely adjustable feathering action when desired.

Notation

T = Horizontal thrust, (lb.)
R = Rotor radius, (ft.)
H = Horizontal rotor drag force, (lb.)
L = Vertical force, (lb.)
Q = Torque, (ft. lb.)
R' = Resultant force, (lb.)
ωR = Tip speed, (ft./sec.)
A = Rotor disc area, (sq. ft.)
ρ = Air density, (slugs/cu. ft.)
$T_c = T/\rho A\omega^2R^2$
$H_c = H/\rho A\omega^2R^2$
$L_c = L/\rho A\omega^2R^2$
$Q_c = Q/\rho A\omega^2R^3$
D = Parasite structure drag, (lb.)
$D_c = D/\rho A\omega^2R^2$
σ = Solidity = Blade area/A
V = Horizontal velocity, (ft./sec.)
$\lambda = V/\omega R$
u = Axial velocity component, (ft./sec.)
$\chi = u/\omega R$
C_{D0} = Blade profile drag coefficient
θ_0 = Basic blade angle
θ_1 = Feathering or flapping angle
i = Inclination of virtual rotation axis to vertical
V_2 = Final slipstream velocity, (ft./sec.)
A_s = Slipstream section area in zone of countervanes, (sq. ft.)
I_V = Aerodynamic lift on countervanes, (lb.)
C_L = Lift coefficient of countervane airfoils
A_V = Countervane area, (sq./ft.)
R_V = Radius to vane center of pressure, (ft.)
$R_A = A_s/A_v$ vane area ratio
$R_R = R/R_v$ vane radius ratio

Part I. Propulsion

Advantage of Rotor Tilt

In order to have surplus power available, over that required for sustentation, for useful performance it is essential that only a relatively small amount of the power and weight be assigned to auxiliary functions. For this reason it is important that the propulsive means

[1] W. F. Durand, E. P. Lesley, *Tests on Air Propellers in Yaw*, N.A.C.A. Report No. 113, 1921.
[2] Alexander Klemin, *An Introduction to the Helicopter*, Mechanical Engineering, Vol. 46, No. 11a, Mid-November, 1924.

selected shall weigh as little as possible and divert a minimum of power from sustentation. The use of the lift screw to provide propulsion also by making it tiltable is most attractive from this point of view because it adds no weight and enables all the power to be used in the critical static, or hovering phase of performance.

Difficulties Encountered

Former investigators have however found propulsion by rotor tilt disappointing,[3] the horizontal component expected on the assumption that the thrust vector would stay in line with the rotation axis not being verified. Instead it was found that the thrust vector of a lifting rotor inclines backward with relation to the direction of translation. In the case of the rigid rotors this translational backward inclination cancels the tilt-induced forward component of thrust at low translational speeds, thus causing the resultant thrust vector to remain substantially vertical regardless of tilt.

An analysis of this condition is illustrated in Fig. 1 which shows that the observed resultant force R' implies the presence of the horizontal force H, acting on the hub, in addition to the axial thrust F.

Theoretical Effect of Feathering

In his analysis of the horizontal flight of a helicopter with vertical axis, Glauert has derived approximate formulas for H_c in the case of a constant pitch and of a pitch periodically varied by feathering.[4]

For constant pitch he gives,

$$H_c = \frac{1}{2}\sigma\lambda\left(\frac{1}{2}C_{Do} + 3\theta_o\chi\right) \tag{1}$$

and for variable pitch, with feathering angle adjusted to the value needed to balance the rolling moment,

$$H_c + \frac{1}{4}\sigma\lambda C_{Do} + \frac{\frac{1}{2}\sigma\lambda\chi\left\{3\chi - \theta_o\left(1 - \frac{9}{2}\lambda^2\right)\right\}}{\left(1 + \frac{3}{2}\lambda^2\right)}. \tag{2}$$

Comparison of the numerical values found by means of these equations shows that the feathering has the effect of greatly reducing H_c.

A more precise derivation by avoiding a questionable approximate assumption leads to the equation,

$$H_c = \sigma\lambda\left\{\frac{5}{4}\theta_o\chi + \frac{1}{4}C_{Do} + \frac{1}{8}\theta_o^2 - 2\left(\theta_o - \frac{3}{4}\chi\right)\right.$$
$$\left.\times\left(\frac{5}{2}\chi + \frac{1}{3}\theta_o + \frac{3}{4}\theta_o\lambda^2\right)\right\}\Big/3\left(1 + \frac{3}{2}\lambda^2\right) + 2\lambda^3 \tag{3}$$
$$\times\left(\theta_o - \frac{3}{4}\chi\right)^2\Big/3\left(1 + \frac{3}{2}\lambda^2\right)^2$$

which still further develops this effect.

[3] O. Flachsbart, G. Kröber, *Experimental Investigation of Aircraft Propellers Exposed to Oblique Air Currents*, N.A.C.A., T.M. No. 562, 1930.

[4] H. Glauert, *On the Horizontal Flight of a Helicopter*, Aeronautical Research Com., R. & M. No. 1157, March 1928.

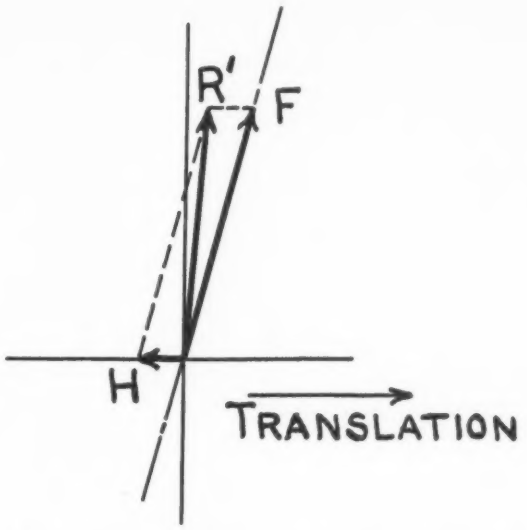

Fig. 1. Force Diagram of a rigid rotor in horizontal translation.

Physical Interpretation of Effect of Feathering

A physical interpretation of the action in the two cases makes clear the reason for this reduction in rotor drag with feathering. In Fig. 2 the circle represents the path of a blade element revolving in the direction of the arrow heads. When revolving in stationary air the drag on the blade element has the same value throughout the revolution and the instantaneous aerodynamic force system of two opposed blade elements is completely represented by the solid arrows, a couple balancing the imposed torque. If the rotor is now placed in a relative wind, indicated by the arrows at the right, the drag on the element in the lower position is increased while that on the upper element is decreased. The dotted arrows describe the new condition. Equilibrium now requires an additional force at the hub equal to the difference between the two blade forces, as shown by the central dotted arrow, which is the rotor drag H.

Feathering the blades so as to reduce the angle of attack on the advancing element and increase the angle on the retreating element has the effect of diminishing the difference between their drags and so of diminishing the drag at the hub correspondingly.

Feathering in the Tilted Rotor

The reduction in rotor drag due to feathering being of numerical importance in the case of the horizontal rotor, as shown by Glauert, the question naturally arises whether the same expedient may not be applied to the tilted rotor to allow the development of adequate propulsion.

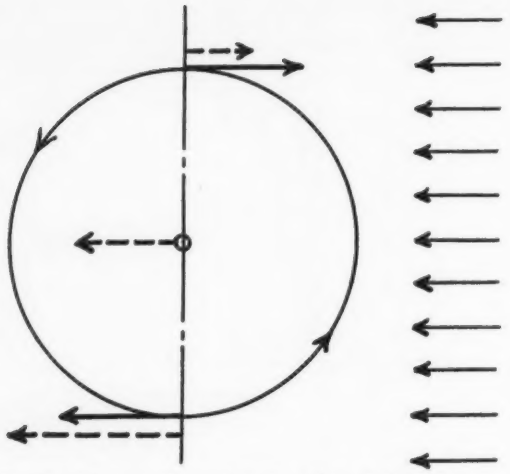

FIG. 2. Diagram illustrating the effect of feathering on drag.

In the rotor tilted to the angle ι in horizontal flight,

$$\begin{aligned} \iota L_e &= D_e + H_e \\ \iota &= (D_e + H_e)/L_e. \end{aligned} \tag{4}$$

D_e and L_e being simple functions of the known or assumed weight and drag characteristics of the machine, only H_e need be computed for a complete determination of ι.

The method of Glauert is seen to be directly applicable to the determination of H_e for the inclined rotor when it is realized that the inclination angle ι has an aerodynamic effect on the blade element identical with that of the feathering angle θ_1. To apply the Glauert equations therefore it is only necessary to substitute $(\iota + \theta_1)$ for θ_1 and to take u as the axial velocity component instead of the vertical component.

We may then write in general,

$$\chi = \left\{\frac{1}{2}\left(L_e^2 + \lambda^4\right)^{\frac{1}{2}} - \frac{1}{2}\lambda^2\right\}^{\frac{1}{2}} + \lambda\iota \tag{5}$$

which reduces for $\lambda > 0.10$ approximately to

$$\chi = L_e/2\lambda + \lambda\iota. \tag{6}$$

Also, for the condition of no rolling moment,

$$\theta_1 = \left\{\frac{8}{3}\lambda\left(\theta_o - \frac{3}{4}\chi\right)\right\} \Big/ \left(1 + \frac{3}{2}\lambda^2\right) - \iota. \tag{7}$$

By means of Eqs. (3), (4), (6) and (7) the propulsive characteristics may be computed for any assumed set of parameters. Fig. 3 shows the influence, so computed, of tip speed ratio λ on required blade angle θ_o, feathering angle θ_1, rotation axis inclination ι, inclination uncompensated for rotor drag, $\tan^{-1} D_e/L_e$, and $(\iota + \theta_1)$, all for the condition of zero rolling moment, for a hypothetical helicopter having the following assumed parameters:

$L_e = 0.0054$ (assumed constant)
Parasite drag area $= 6.25$ sq.ft.
Solidity $= 0.05$
$C_{Do} = 0.010$

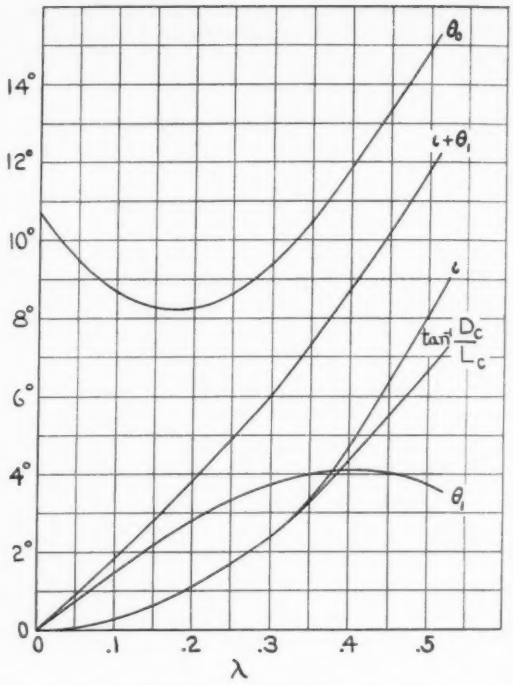

FIG. 3. Characteristics of a typical feathering or flapping rotor as influenced by horizontal velocity.

There is no appreciable divergence between ι and $\tan^{-1} D_e/L_e$ until the tip speed ratio exceeds 0.35. The conclusion is thus reached that, within the practical operating range of tip speed ratios, balanced rolling moment implies also balanced drag moment, and for approximate results the rotor drag component may be neglected in the feathering type of rotor.

The feathering angle curve is of interest in showing that there should be no difficulty in maintaining lateral balance with a single supporting rotor.

Application to Flapping

It is well known[4] and can be readily demonstrated that the feathering and flapping methods of rotor balancing are aerodynamically identical. The above conclusions therefore apply equally well to flapping rotors, with the only difference that in flapping the inclination angle ι applies to the virtual rotation, or cone axis, the shaft axis inclination being $(\iota + \theta_1)$. The curve of $(\iota + \theta_1)$ in Fig. 3 gives the shaft inclination required in a rotor of the articulated, or flapping type.

Performance

The power required for any condition of level flight is obtained by means of Glauert's equation,

$$Q_e = \frac{1}{8}\sigma C_{Do}(1 + \lambda^2) + \chi L_e \tag{8}$$

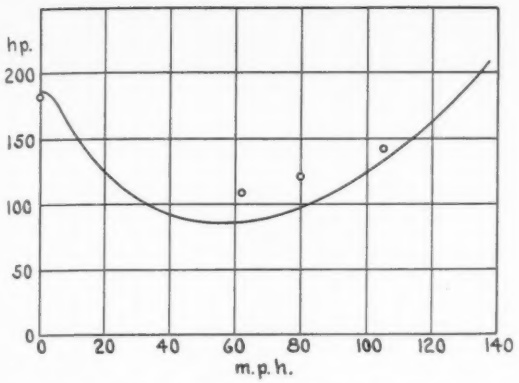

FIG. 4. Theoretical performance curve of hp. required in level flight, with experimental points, of a 3,000 lb. helicopter having a feathering rotor.

The solid line of Fig. 4 gives the horsepower required in level flight for a helicopter having the following assumed parameters:

Weight = 3,000 lb.
Rotor diameter = 44 ft.
r.p.m. = 170 (assumed constant)
$\sigma = 0.0671$
$C_{Do} = 0.015$
Parasite drag area = 6.25 sq.ft.

The hp. required for static sustentation ($V = 0$) has been approximately corrected for slipstream rotation, neglected in the Glauert derivations, by multiplying the calculated hp. by the factor,

$$1/(1 - Q_c/L_c)^2.$$

EXPERIMENTAL CONFIRMATION

In order to check experimentally these extremely promising theoretical indications wind tunnel tests were conducted using a two bladed rotor with adjustable feathering mechanism. In all the tests a constant blade angle of ten degrees was used, equivalent aerodynamically to 11.5° on account of the cambered section, and the inclination and feathering angles varied. The solidity was 0.0671. Four experimentally determined points are shown by the small circles in Fig. 4.

It should be noted that the experimental points, with the exception of the static point, are not precisely comparable with the theoretical curve because in one case the blade angle was constant and in the other the lift coefficient was assumed constant. The discrepancy is in the direction of further reconciliation and is of slight consequence except at high speed. The experimental procedure is simplified by maintaining the blade angle constant, while constant L_c is more nearly what would be aimed at in practice and makes the solution of the equations much easier. The effect of constant blade angle is to cause a variation in r.p.m. qualitatively similar to that of θ_o in Fig. 3.

Direct confirmation of the physical interpretation of drag reduction by feathering is found in the test

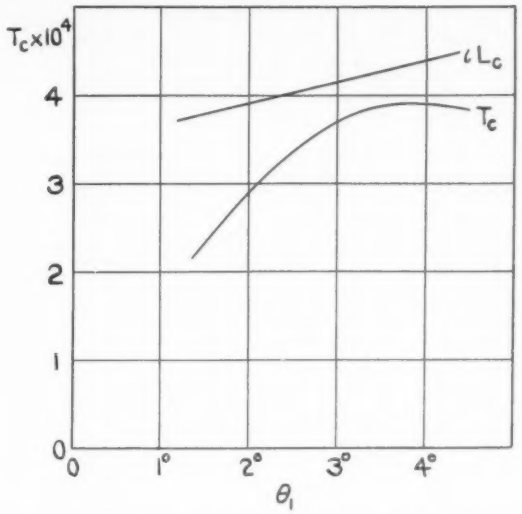

FIG. 5. Effect of feathering on thrust development.

results. Thus Fig. 5 shows the observed correlation between thrust coefficient and feathering angle for a typical set of readings at one value of inclination and tip speed ratio ($\iota = 4°$, $\lambda = 0.187$). The curve of ιL_c is included for reference. The similarity to an inverted drag curve is at once apparent.

Part II. Torque

NEED FOR TORQUE COUNTERACTION

The sustentative and propulsive advantages of the single, feathering or flapping rotor of large diameter must remain purely academic unless means can be devised for absorbing the large torque reaction moment developed by it.

POWER LOSSES

The first requirement of any device employed for torque neutralization, as in the case of propulsion, is that it must consume a minimum of power and must have a minimum weight. To illustrate the seriousness of this problem it may be stated that all otherwise operative torque elimination schemes hitherto employed in connection with the single lift screw have consumed in the neighborhood of 50% of the power available, besides adding greatly to the weight of the machine. The inevitable result has been that practically no power was left for performance.

THE COUNTERVANE PRINCIPLE

These considerations led the author to a theoretical and experimental investigation of the countervane principle, well known in turbine and blower practice, as a means of torque neutralization in the single screw helicopter. The countervane is fundamentally attractive in that it employs for its actuation only the energy

otherwise wasted in the rotor slipstream. The questions naturally arising in connection with its application to the helicopter are:

1. Is the momentum of the slipstream sufficient for the purpose?
2. Can an arrangement of such vanes be devised which will not seriously impair the functioning of the helicopter in other respects?
3. Will not interference between the vanes and the rotor blades reduce lift seriously?
4. Are weight and parasite structure unduly increased?

Static Lift Theory

From momentum theory, for the static lift condition,

$$V_2 = (2L/\rho A)^{\frac{1}{2}}. \tag{9}$$

If the countervanes could be placed in the fully contracted slipstream of the rotor this value could be taken as the continuous velocity of the air over the vanes. It is however not practicable or desirable to place the vanes so far from the rotor. Some assumption must therefore be made to take care of the different conditions existing in the partially contracted slipstream. The simplified picture of the slipstream here used for this purpose is that of an assembly of wedges having the velocity V_2 separated by wedges of stationary air, the velocity wedges drawing together until they form a complete cylinder in the contracted stream. The vanes receive impulses only during the times of passage over them of the velocity wedges. The mean force developed is then less than would be the case in the fully contracted stream by the ratio: contracted slipstream area/partially contracted area. Since the contracted area $= \frac{1}{2} A$, this ratio may be written, $A/2A_s$.

Whence

$$L_v = \frac{1}{2} \rho C_L A_V V_2^2 (A/2A_s).$$

For equilibrium

$$Q = L_V R_V.$$

Combining and reducing,

$$C_L = (2 A_s R/A_V R_V)(Q_c/L_c).$$

A_s/A_V and R/R_V are nondimensional parameters and as such are advantageously replaced by the nondimensional symbols R_A and R_R. Then

$$C_L = 2 R_A R_R Q_c/L_c. \tag{10}$$

Numerical solutions disclose that this equation is satisfied by quite reasonable proportions.

Vertical Ascent and Descent

It can be shown that vane efficacy increases with vertical climb and is somewhat diminished in slow descent with low power. The latter consideration is not considered important however because any practical machine must be equipped for autorotative descent at low velocity which could at any time be substituted for power drive in descending. The static state is therefore critical in vertical operation.

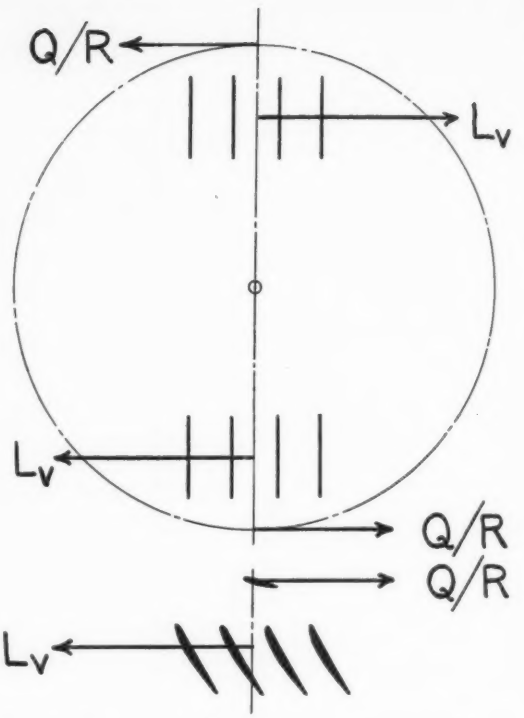

Fig. 6. Diagram of countervane arrangement and force balance.

Arrangement of Vanes

Two essential conditions must be observed in locating the countervanes with relation to the rotor axis. In the first place they must provide an approximately complete force balance. Since the torque system is a couple it follows that the countervane forces must also be disposed as a couple. This can be achieved effectively only by a generally symmetrical placing of vanes relative to the axis. The second condition is that the vanes present a minimum of obstruction to forward flight, in other words they must be approximately parallel to the flight direction. The arrangement of vanes made mandatory by these considerations is shown diagrammatically in plan and front elevation in Fig. 6, the arrows indicating the force system when in equilibrium.

Static Tests

A frame was attached to the rotor shaft housing of the model so as to support two groups of vanes. Vane area was altered by varying the number of vanes in each group from one to four. The vanes were mounted so as to be universally adjustable and were in addition provided with trailing edge flaps.

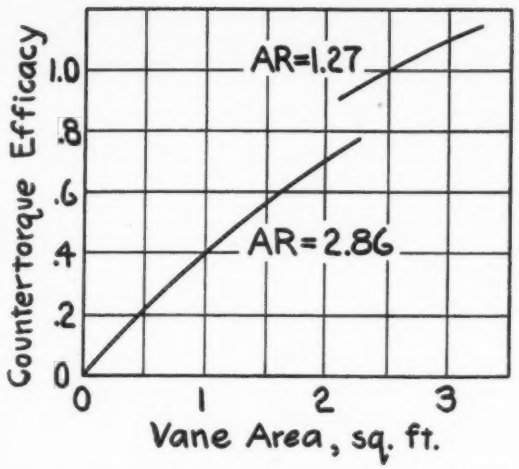

FIG. 7. Variation of available countertorque with vane area on wind tunnel model.

Vanes with two plan forms were tested, both having section 2412. One of these had rectangular tips and aspect ratio 2.86. The other was circular in plan form, corresponding to aspect ratio 1.27. The rectangular type was tested with one and two vanes to the group, the circular type with three and four. The static results for the optimum settings are given in Fig. 7 as determined, without scale or other correction, from the wind tunnel balances, countertorque efficacy being defined as the ratio: countertorque/rotor torque.

The superiority of the circular vanes for the purpose is apparent, as was to be expected from standard data.[5] A negative torque, that is in the direction of rotation, of considerable amount was actually recorded on the balances in the setting with eight vanes. The steepness of the curve shows that still more effect could have been obtained with greater vane area, an indication that the available slipstream momentum was not exhausted.

The maximum lift coefficient attained by the vanes according to Eq. (10) was about 1.26. This is in good agreement with expectations from theory in view of the low test value of RN, about 60,000. Clearly a considerably higher C_{Lmax} would be developed with larger scale.

Effect of Vanes on Lift

It was anticipated that there would be some loss of lift due to the drag of the vanes in the slipstream. This proves however not always to have been the case. Consistently in all the static tests the net lift increased with increase of vane angle of attack and fell below the initial value only when extreme settings were reached. The upper curve of Fig. 8 shows the maximum effect of this kind obtained, which was with eight vanes and a flap setting of 15°. The L_e values have been corrected for the tare drag of the supporting frame.

[5] C. H. Zimmerman, *Characteristics of Clark Y Airfoils of Small Aspect Ratios*, N.A.C.A. Report No. 431, 1932.

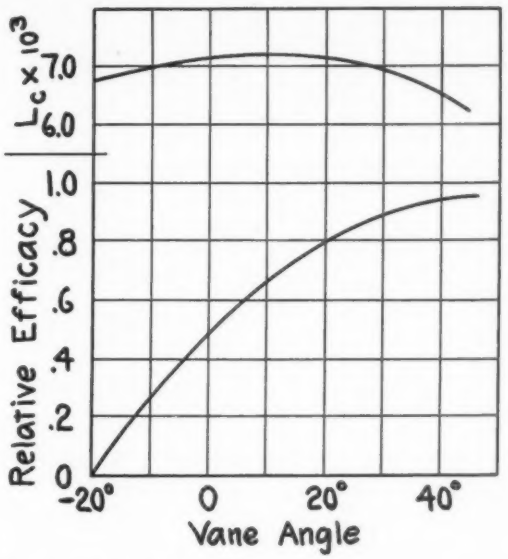

FIG. 8. Effect of vane angle on lift and countertorque.

A clue to the reason for this effect is found in the lower curve of Fig. 8 which gives the variation with vane angle of countertorque expressed as a fraction of the maximum observed value. This curve is noteworthy for its low slope and wide range of apparent angle of attack. The negative zero position is due to slipstream rotation and is in good agreement with the theoretically expected rotation angle. The large apparent angles of attack were undoubtedly not the true relative angles, the airflow being straightened out by the presence of the vanes. In the case of the largest angles the rotation may even be reversed in the zones of the vanes. Since without countervanes the rotation loss is more than 10% of the lift, it seems reasonable to conclude that some of this loss is recovered by the vanes during the straightening of the flow and that it is again lost when the rotation is reversed.

Countervane Efficacy in Forward Flight

The application of wind to the rotor and vanes causes a great change in the flow pattern. The following five new influences affect the countertorque efficacy:

(1) Reduced torque due to reduced hp. required.
(2) Reduced vertical induced flow component.
(3) Increased resultant airflow due to horizontal component.
(4) Change in turbulence characteristics.
(5) Displacement of vertical component relative to vanes.

The effect of the first three can be readily determined from the data in Part I, the resultant airflow velocity over the blades being

$$\omega R\,(4\lambda^2 + \lambda^2)^{\frac{1}{2}}$$

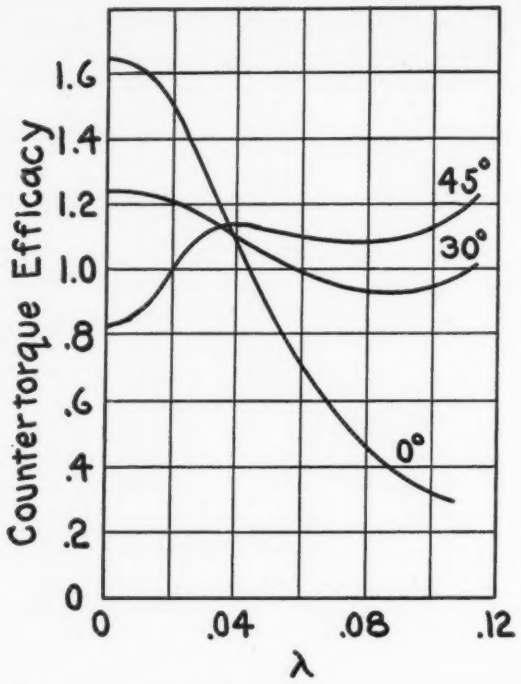

FIG. 9. Effect of forward speed on full scale countertorque efficacy for three wind-span angles.

A computation of the maximum efficacy obtainable on the assumption that the vanes are adjustable so as to meet the relative wind to the greatest advantage shows a slight reduction in potential efficacy at speeds below $\lambda = 0.05$. The amount of this reduction is rather uncertain because of the unknown numerical weight of influences 4 and 5.

SOLIDITY, SCALE AND TARE CORRECTIONS

Solidity has an important influence on the countertorque efficacy as can be seen from consideration of Eq. (8) which shows that Q_e is a function of solidity. Low solidity is advantageous from this point of view and the lowest practicable value should be used.

Data given in standard reference works lead to a C_{Lmax} scale correction factor of about 1.40 for the conversion of the model RN to full scale.[6]

In addition to these influences on the model there was ample evidence that the airflow velocities were reduced by an appreciable but undetermined amount owing to the obstruction of the relatively bulky supporting structure.

There is some uncertainty as to whether the full gain in C_{Lmax} expected could be used to advantage. In estimating from the tests what is to be expected at full scale therefore the following corrections have been applied:

[6] K. D. Wood, *Technical Aerodynamics*, Cornell University, 1933.

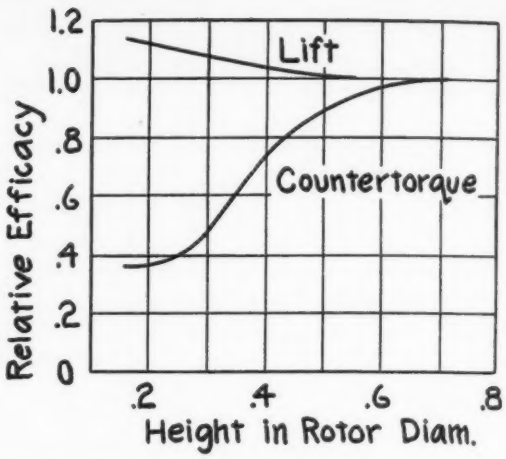

FIG. 10. Effect of ground on static countertorque and lift.

1. Rotor drag scale correction.
2. Vane structure tare drag correction.
3. Determinable deviations from the true flight conditions of Part I.
4. Conversion from model solidity of 0.0671 to 0.05.
5. Multiplication of the observed efficacy by the factor 1.30 to allow conservatively for C_{Lmax} scale effect plus influence of flow obstruction by the structure.

RESULTS OF TESTS WITH WIND

In the tests with wind three settings of vane span relative to the wind were used, namely 0°, 30° and 45°. The results, corrected as noted above, are given in the curve of Fig. 9 for available countertorque efficacy at full scale with the vane area ratio of the eight vane model set-up. The dip in efficacy at transition speeds is more pronounced than that expected from the incomplete theory but at no place fails to have a good margin over complete torque neutralization for the combined curve.

To obtain these results in practice the vanes must be adjustable by rotation in the vertical plane as well as controllable for angle of attack. A two position adjustment would suffice.

GROUND EFFECT

It was anticipated that proximity to the ground would give rise to two modifications in performance: (1) Increase in lift per hp., and (2) Decrease in countertorque owing to obstruction of airflow over the vanes. To determine the quantitative importance of these effects a ground board, movable with relation to the rotor, was added to the static test apparatus.

The curves of Fig. 10 portray the results of the ground board tests, lift and countertorque efficacies being plotted as fractions of their static free flight values against height of the rotor hub above ground in fractions of the rotor diameter. The lift curve shows

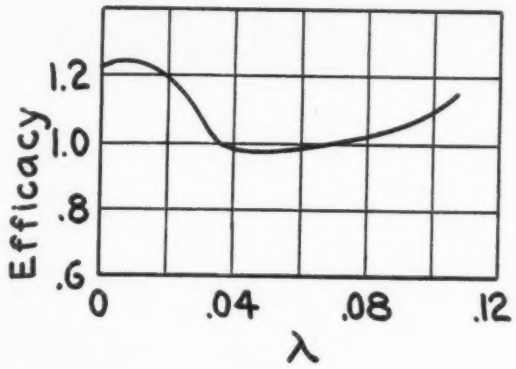

FIG. 11. Effect of forward speed on full scale countertorque efficacy at ground level with model proportions.

why so many helicopters have been able to rise a few feet and no farther. The curve of countertorque efficacy indicates that the rotor should be placed as high above ground as mechanical and weight considerations will permit. A height of 0.40 rotor diameters seems to be about the limit of economical compromise. With these proportions the maximum efficacy at the ground level with no wind, was found by reference to Figs. 9 and 10, to be 1.22.

COMBINED GROUND AND WIND

The final problem has to do with the combined effect of ground and wind, the typical example being that of a helicopter holding itself stationary just off the ground in a wind of low velocity. It is evident that the ground effect on countertorque will diminish rapidly with wind owing to the lesser vertical flow component and the reduced obstruction of the ground to oblique flow.

Assuming the dynamic effects on the vanes to be proportional to those on the ground it is found that reduction of vane efficacy due to ground and wind equals reduction of efficacy due to ground alone times

$$\left\{1 - \lambda/(4\,\chi^2 + \lambda^2)^{\frac{1}{2}}\right\},$$

which may be considered a reasonably close basis for evaluating the combined effect. In Fig. 11 the combined ground condition has been superimposed on the optimum envelope curve from Fig. 9. It was not feasible with the apparatus available to obtain reliable wind tunnel data for combined ground and wind. The quantitative indications of Fig. 11 remain therefore in some doubt. Qualitatively however it seems clear that the critical condition for torque control by countervanes is that of a 10 to 15 m.p.h. wind while the helicopter is at ground level. If sufficient vane surface is furnished for these circumstances, which are fortunately easy to check in a full scale machine, there will be ample surplus efficacy for all other flight phases.

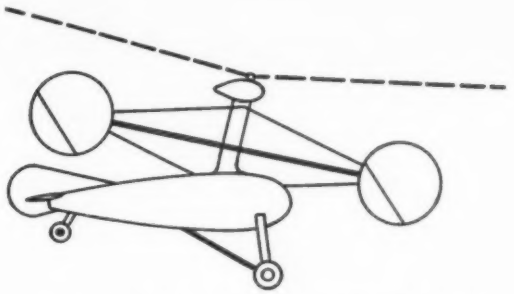

FIG. 12. Helicopter with tilting rotor propulsion and countervane torque control.

EFFECT OF VANES ON PERFORMANCE

The weight of the requisite vanes and supporting structure will be about 10% of the full load weight of the machine. In static flight this is equivalent to a consumption of 10% of the power required for sustentation, or about 7% of the total power. In free static flight this loss will be somewhat reduced by the beneficial effect of slipstream straightening.

The top speed will be reduced by the parasite drag of the vanes and supports, estimated at three square feet for the example of Fig. 4. This was included in the total of 6.25 square feet assumed. The performance curve of Fig. 4 is evidence therefore that the countervanes should not seriously impair the attractive propulsive characteristics of the inclined rotor.

ARRANGEMENT

A diagrammatic side elevation in forward flight attitude of a helicopter having a single, articulated lift screw and countervane torque control is shown in Fig. 12, the proportions complying in general with the theoretical and experimental requirements.

Acknowledgment: Grateful acknowledgment is made to Mr. E. Burke Wilford for the loan of valuable apparatus.

Change of Boiling Point of Liquid Oxygen at High Altitudes

JEAN PICCARD, *University of Minnesota*

(Received August 1, 1936)

AFTER having been five hours in the stratosphere in a sealed gondola the author and Mrs. Piccard were coming down. Conditions were very comfortable, although it was not known what was below the cloud sea which had closed under the balloon a few minutes after the start from Ford Airport, Dearborn, Mich.

The inside barometer was constant and the outside barometer was rapidly approaching the level of the first instrument. At 10,000 feet both barometers were equal and the doors of the gondola were opened allowing the author and Mrs. Piccard to breathe natural air again. At this moment the oxygen stopped escaping from the vacuum insulated copper bottle, and gave the impression that all the oxygen was used up. There was not, however, much time to think about this problem because the balloon was now entering the cloud sea and was cooling rapidly. Ballast had to be thrown out continuously and landing operations had to be made. In a few minutes the balloon was through the clouds and it was a great relief to see under it not the open ocean but a charming eastern farming country. The feeling of safety was soon interrupted when it was seen that the balloon was aiming with considerable speed straight towards the chimney of a farm house. Very fortunately two heavy outside sandbags had been kept, in addition to some lead ballast inside the gondola. Mrs. Piccard, the author's pilot called: "Fire two bags!" and less than a second later two electric blasting caps exploded at the bottom of the bags, instantaneously emptying 160 lbs. of sand into the farmer's barnyard. A few minutes later a landing was safely made in a cluster of elm trees.

The oxygen had been forgotten, but, three hours after the landing, it began to boil again, filling the lower part of the gondola with dense fog. What had happened?

During the stay in the stratosphere the inside pressure of the gondola corresponded to an altitude of 10,000 feet, the altitude at which the doors had been closed at the beginning of the ascent. At this reduced pressure oxygen boils at a considerably lower temperature and the liquid had cooled to its new boiling point. When the doors were opened, at the descent, the pressure in the gondola began to increase and the theoretical boiling point of the oxygen rose gradually to normal. For this reason it had stopped boiling because no liquid boils when it is cooler than the boiling point corresponding to the surrounding pressure.

In the case of a modern stratosphere balloon with a sealed gondola the described phenomenon, the non-boiling of liquid oxygen on the way down, is no more than an interesting observation, a necessary result of well-known scientific facts. The oxygen will only stop boiling after the doors have been opened and from this time on no more oxygen is needed.

Lately, when the author heard about high altitude airplane flights being prepared, this story came back to his mind and he realized the imminent danger in which aviators will be thrown if they rely on a breathing mask supplied with oxygen from a bottle of the liquefied gas, as is frequently done.

Liquid oxygen, even when kept in a well-insulated vacuum bottle, is continuously boiling, and this boiling produces the gas needed for breathing. If the volume of gas produced in this manner is not sufficient, its amount is increased by the closing of a small valve which prevents the gas from escaping and which forces a corresponding volume of liquid oxygen out of the bottle. This liquid oxygen when flowing through a warm metal tube outside the bottle is transformed into gas. A given volume of liquid oxygen produces about one thousand times its volume of oxygen gas.

From the author's experience, as related before, it becomes evident that the aviator who relies on such a gas mask is in very real danger of suffocation on his way down. This danger should be brought to his attention:

While the airplane is rising and the atmospheric pressure diminishing, the boiling point of liquid oxygen is constantly going down. The liquid is therefore boiling more violently and is cooling far below its normal boiling point. When the ceiling is reached and the pilot starts his return voyage to earth, the atmospheric pressure on his oxygen apparatus immediately begins to rise and the liquid stops boiling. It is not merely a slower boiling which takes place. The boiling and gas production stop entirely and, in addition, the cold liquid begins to condense nitrogen and oxygen at its surface. In this manner air is even sucked back from the gas mask into the bottle. This means that as soon as the pilot starts going down he will be cut off from any oxygen supply for the rest of his voyage.

This, in the stratosphere, means the seeing of black spots before the eyes, followed by unconsciousness and death, all within a few seconds.

Engineering Applications of Boundary Layer Control

RAYMOND B. MALOY, *Philadelphia, Pa.*

(Received June 29, 1936)

THE rapid evolution of aircraft is now at a stage of development where it is profitable to give more attention to certain aerodynamic refinements, heretofore viewed as being impractical or uneconomical. The present line of progress has very nearly reached its limit in meeting the demands for higher top speeds in transport aviation and reduced minimum speeds in sportscraft. The field of aerodynamics offers some interesting possibilities in increasing the overall efficiency of the airplane by improving the characteristics of the airfoil sections used. With this idea in mind, an evaluation of the state of development in the special branch known as boundary layer control, seems timely.

The lift and drag characteristics of an airfoil are very sensitive to flow conditions in the thin layer of air nearest the surface of the wing. Within this thin strata of air, known as the boundary layer, the velocity varies from zero at the surface of the profile to a velocity equal to that of the free air stream. The energy in this layer is very important as it is the inability of the lagging boundary layer to move downstream against the pressure gradient of the wing that results in the flow separation or burble associated with the stall. Various methods of energizing the boundary layer will delay this flow separation to much higher values of lift. The most commonly used method of adding this energy has been the use of a slot on the leading edge of the wing. The properties of such an arrangement, however, are well known and will not be discussed in this paper. Attention will, instead, be directed to the promising results obtained by actual sucking or blowing air from slots in the wings.

Owing to the difficulties involved in the obtaining of experimental data in this field, progress has been slow. The work of J. Ackeret[1], A. Betz and Oskar Schrenk,[2, 4] conducted at the Aerodynamic Laboratory in Göttingen, has been outstanding. The experimental work of the group has been largely restricted to the use of suction slots in increasing the lift and reducing the drag of thick wing sections. In this country, M. J. Bamber[3] utilized a relatively thin wing with a backward opening slot. Although both suction and pressure were used for the same slot, the form of the slot was such as to favor distinctly the pressure method of control.

Considerable difference of opinion still exists as to the type of wing section best suited to application of boundary layer control. For that reason, most experimental work includes tests both of thick sections (30% thickness) and thin sections, the latter usually with a flap arrangement. From the standpoint of the lift coefficient, the thick section gives slightly higher values for the same expenditure of power, as compared to the thin section with flap. This advantage is further increased by the small manifold duct losses and the more uniform pressure distribution along the length of the wing. This problem may become quite acute in the case of the thin section, especially in a tapered wing. The thick wing has always appealed to the structural man because of the possibilities offered to reduce weight as a result of increased beam depth. In addition, the added storage space is desirable even to the point of completely housing the power plant inside the wing. All these advantages are to a certain degree offset by the large minimum drag of such a section. This drag can be reduced to a value comparable with that of a normal section, but involves a continuous power output in the form of pressure or suction.

In the discussion of the merits of the thin wing section, the addition of flaps will be assumed throughout, as it presents certain readily apparent advantages. In the event of the failure of the power plant, a flapped wing airplane would be perfectly capable of making a normal landing at slightly higher speed, whereas, the thick wing plane might be in serious difficulty. The flap has the further advantage of shifting the lift curve, giving a lower angle of zero lift and maximum lift occurring at a correspondingly low angle of attack. To obtain a lift coefficient of the order of 3.0 or 4.0 might necessitate going to an angle of attack of approximately 30 degrees without flaps. Such excessive angles would increase the problem of landing gear design. The thin section would require a power output only for limited periods of time, such as take-off or landing, although a small continuous expenditure of power might be worth while in reducing the profile drag of the wing. A word of caution should be added here in regard to the ground effect on a flapped wing using suction control. The latest tests of O. Schrenk[4] indicate an appreciable decrease in the maximum lift coefficient in the presence of the ground. Under such

[1] J. Ackeret, *Removing Boundary Layer by Suction*, N.A.C.A. Tech. Memo. No. 392, 1927.

[2] Oskar Schrenk, *Experiments with a Wing Model from which the Boundary Layer is Removed by Suction*, N.A.C.A. Tech. Memo. No. 534, 1929.

[3] M. J. Bamber, *Wind Tunnel Tests on Airfoil Boundary Layer Control Using a Backward-opening Slot*, N.A.C.A. Rept. No. 385, 1931.

[4] Oskar Schrenk, *Experiments with Suction Type Wings*, N.A.C.A. Tech. Memo. No. 773, 1935.

conditions a high wing aircraft would be more efficient. Summing up the case for the two types of wing sections, it is probable that the first venture into the practical application of boundary layer control will be with a normal section equipped with a flap, because of its greater safety in event of power failure. Ultimately the thick section will prevail because of its many advantages.

The advisability of using suction or pressure in controlling the boundary layer is a question that has not been definitely settled. A comparison of the two types of control as to power required to obtain a certain value of lift should be a good criterion of the relative efficiency of the two methods. For the purpose of the comparison, the two most recent experimental works on the subject, O. Schrenk's tests[4] using suction, and M. J. Bamber's tests[3] using pressure, are presented in Fig. 1. O. Schrenk's tests were run at a Reynold's Number of approximately 600,000 and Bamber's tests at Reynold's Number of approximately 445,000. End plates were used in both series of tests.

The standard procedure in discussing boundary layer control data is to reduce the quantity of air flowing and the pressure in the wing to absolute coefficients of the form:

$$C_Q = \frac{Q}{VS} \text{ and } C_P = \frac{P}{q}$$

where, Q = Quantity of air/unit time
S = Area of wing
V = Velocity of flight
q = Dynamic pressure
P = Pressure inside the wing

The power required is expressed in terms of an equivalent drag coefficient, C_{DS}, which does not include losses in the blower or ducts. The power required = $C_{DS}\, q\, V\, S$, where $C_{DS} = C_P C_Q$.

An examination of Fig. 1 shows that the power required coefficient, C_{DS}, is considerably less for both suction cases as compared with the pressure method. The curve representing pressure breaks away sharply for values of C_L above 2.0, and the power required coefficient mounts rapidly. This apparent superiority of the suction method of control is probably due to the double effect obtained by sucking air through a slot flush with the surface of the wing. This theory attributes the increased lift of a suction wing to two distinct conditions; first, the simple removal of the retarded boundary layer, and secondly the sink influence, which is due to the change in pressure distribution over the wing surface in the presence of a suction slot. The latest tests of O. Schrenk[4] indicate that this last influence can be quite appreciable with the proper slot.

With these data before us, it is interesting to consider the possible lines of development open to a practical application of boundary layer control. No attempt will be made to give an analysis of the gains possible in the line of speed range, rate of climb, top speed, etc., as

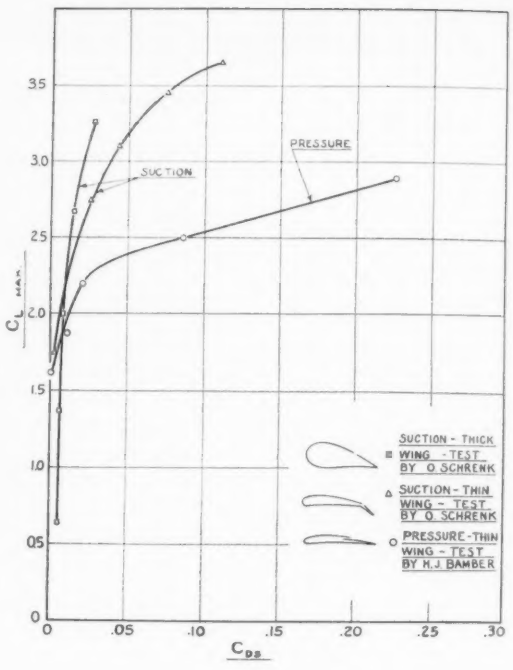

FIG. 1.

this field has been covered in previous papers. It is the purpose of the following numerical examples to give concrete evidence of the actual values of power required, pressures and quantities of air involved in a practical application of boundary layer control. As the first application will probably be in the direction of reducing the landing speed in an effort to make flying safer for the average man, the following example of a light airplane is given:

Example 1.

Characteristics

$W = 1700$ lb. Power = 100 hp.
$S = 200$ sq.ft.
$V_{max.} = 110$ m.p.h. $C_{L max.} = 3.0$

$$V_{min.} = \sqrt{\frac{2\,W}{C_L \rho A}} = \sqrt{\frac{2 \times 1700}{3.0 \times \rho \times 200}} = 48.9 \text{ ft./sec.}$$
$$= 33.4 \text{ m.p.h.}$$

Using a thin wing section with flap, the following values are from the data used in plotting the curves of Fig. 1: $C_{DS} = .039$, $C_Q = .013$, $C_P = 3.0$. Assume blower and duct efficiency = 70%.

$$\text{Power required} = \frac{C_{DS} S\, q\, V}{.70} = \frac{.039 \times 200 \times q \times 48.9}{.70}$$
$$= 1.550 \text{ ft. lb./sec.} = 2.81 \text{ hp.}$$

Quantity $= C_Q V S$ Pressure $= C_P q$
$= .013 \times 48.9 \times 200$ $= 3.0 \times q$
$= 127.1$ cu.ft./sec. $= 8.51$ lb./sq.ft.

It can be seen from the example that the power required is quite nominal, amounting to about 2% of the total power of the engine unit. On the other hand the quantity of air to be handled is sufficient to require care in the layout of manifolding and ducts.

The recent interest in transport aviation in the substratosphere (35,000 to 50,000 feet) seems to fit in admirably with the advantages of boundary layer control. One of the biggest problems of high altitude flight is that of obtaining sufficient supercharging to maintain sea level power and cabin pressures. This equipment necessarily entails additional weight with a consequent increase in wing area and profile drag. A system whereby the cabin supercharging equipment would be used to control the boundary layer for take-off and landing would increase the efficiency of the entire plane by taking care of the additional weights involved without increasing the wing area or drag. The second example is based on the characteristics of the Douglas DC-2 which we will assume to be converted for flight in the substratosphere.

Example 2.

Douglas DC-2

$W = 18{,}000$ lb. Power $= 1420$ hp.
$S = 940$ sq.ft. $C_{L\max.} = 3.0$
$V_{\min.} = 61$ m.p.h.

Assume a thin section with flap as in the previous example. Maintaining $V_{\min.} = 61$ m.p.h., the weight of the plane could be increased to take care of the supercharging equipment to the following extent.

$$W = \frac{C_L A \rho V^2}{2} = \frac{3.0 \times .00237 \times 940 \times 88^2}{2}$$
$$= 25{,}900 \text{ lb.}$$

It is improbable that such a weight increase would be necessary and the wing area could be reduced a slight amount. The power required would be:

$$\text{Power required} = \frac{.039 \times 940 \times .00237 \times 88^3}{2 \times .70}$$
$$= 42{,}200 \text{ ft. lb./sec. or } 76.8 \text{ hp.}$$

$Q = .013 \times 88 \times 940 = 1075$ cu.ft./sec. $\qquad P = 3.0 \times q = 27.5$ lb./sq.ft.

The recent articles by A. L. Klein[5] and J. E. Lipp,[6] discussing the problems of flight in the stratosphere, indicate the adequacy of the cabin supercharger equipment to meet the demands of boundary layer control. It would merely be necessary to provide slots in the wing to act both for controlling the boundary layer and for providing an inlet for the cabin superchargers. Although the greatest advantage of boundary layer control lies in the field of increased lift, it is also possible to affect small reductions in drag due to the jet reaction of the air expelled to the rear. In the suction method of control, the jet reaction will depend on the ratio of jet velocity to the plane velocity, which in turn depends on the size and direction of the discharge opening. In the pressure method of control, the jet reaction is right at the slot and shows up directly in the measured drag of the airfoil. For the profile shown in Fig. 1, C_D becomes zero for a value of $C_{Ds} = .04$. Using such a value, the power required, pressures, and quantities of air become excessive due to the high plane velocity. It is possible that the same results can be accomplished more efficiently using suction.

The numerical examples given are not to indicate that boundary layer control has reached a stage of development where it is ready to be applied to aircraft as it now stands. It is rather an indication of future possibilities with a little development work in the field of design of efficient ducts, and experiment with types and combinations of slots and their locations on the airfoil. Investigation of combinations of suction and pressure methods of control, and the behavior of the split flap would be desirable.

Conclusions

(1) Serious consideration of the possibilities of a practical application of boundary layer control is justified by the demand for more efficient aircraft.

(2) The power requirements of successful boundary layer control are not prohibitive.

(3) In the light of present experimental data, the suction principle of control is superior to the pressure method.

(4) Boundary layer control as applied to sub-stratospheric air transports promises great possibilities for the future.

(5) A very great need exists for further experimental research as to slot dimensions and locations, the design of ducts, and various flap and suction combinations.

[5] A. L. Klein, *Methods of Cabin Supercharging and Their Necessary Systems*, Journal of the Aeronautical Sciences, Nov. 1935, Vol. 3, No. 2, p. 58.

[6] J. E. Lipp, *Structural Features of Supercharged Cockpits and Cabins*, Journal of the Aeronautical Sciences, Nov. 1935, Vol. 3, No. 2, p. 61.

Letters to the Editor

To the Editor September 14, 1936
JOURNAL OF THE AERONAUTICAL SCIENCES
Rockefeller Center, N. Y.

Dear Sir:

My letter, published in the July issue, was primarily intended to bring about a consideration of problems attending the production and supply of special aircraft fuels with octane ratings of the order of 100. I am interested, but somewhat puzzled, at the tenor of the letters from Messrs. Heron and Nutt which appear to refute the existence of any serious problem in this connection.

These gentlemen appear to labor under some misapprehension as to the part which the oil industry may be logically expected to play in supplying this fuel. Under the circumstances, further comment seems desirable.

If such fuel is to be relied upon for military purposes, the matter of adequate supply in case of emergency presents serious concern. If the supply is to be developed commercially so that it may be available in time of war, fuel cost is also a matter of serious concern, since this will govern its commercial use, as Mr. Heron points out.

The oil industry has been in no sense backward in chemical development, but such development has necessarily been governed by available returns. In Mr. Nutt's rather naïve statement that "The oil industry to date has apparently been fortunate in having a product which was practically a raw material which requires very little processing . . .", he inadvertently gives the clew to the economic function of the oil industry, which has been to make available petroleum products in large quantities at minimum cost to the consumer. No doubt in time, as raw materials fail and processing becomes more complex, the oil industry will change to cope with circumstances. When it does, however, costs will inevitably rise to constitute reward for new development. Hydrogenation of coal to produce oil is an accomplished fact but at a cost which makes it uninteresting for the present.

The cracking process, developed by the oil industry, has served the primary function of changing the boiling range of hydrocarbons to produce volatile fuels and it can do so with a moderate shrinkage in liquid products. When it is called upon to not only change the boiling range but to increase octane rating, the shrinkage in liquid products recovered increases apace, having about doubled during the past ten years as a result of increasing demand for anti-knock properties. The wasteful practice of reforming gasoline for the sole purpose of increasing its octane rating has added a new liquid loss to refinery operations. Polymerization plants have had little influence on this loss in liquid products, which has amounted to many millions of barrels, since these plants are but recent additions to the refinery. Their function will doubtless be a useful one in reducing this loss but they cannot be expected to recover more than part of it and they most certainly will add to refinery cost and heat requirements.

Distillates of high octane rating can be made by cracking but such procedure does not yield uniform compounds and, whereas octane values can be produced, the difficulty lies in treating to produce a stable product and yet retain the anti-knock rating. To obtain reliability and uniformity in aircraft fuels it seems probable that definite compounds with known characteristics must be made which requires synthesis and which involves still another step in refining and more and different equipment.

To consider that the industry can equip itself suddenly to produce an adequate supply for 3000 or 4000 ships on a war footing because 2,000,000 or 3,000,000 gallons have been purchased by the Army, is certainly optimistic. Likewise, to expect its price structure to be of the order of present aviation gasoline (8 to 10c per gallon) is at present unwarranted. To consider a comparison with mineral turpentine or tractor fuel, which are virtually but cuts from a fractionating tower, is obviously not to the point. Possibly a comparison with synthetic solvents, such as iso-propyl alcohol, which sells for 55c per gallon in drum lots and costs probably half as much to make, would be nearer to the subject, for the present at least. There appears to have been some misunderstanding of statements contained in my letter which may account, in part, for differences of opinion. One surprising misconstruction on the part of Mr. Beall* however seems inexplicable. To avoid further misunderstanding, I desire to make it clear that I do not belittle the performance of high octane fuel or its advantages which are ably pointed out by Mr. Heron. In fact, I repeat my statement in the 1st paragraph of my letter:

"Granting that the performance of the carbureting engine is correspondingly enhanced by fuel of high anti-detonating properties, it must be borne in mind that limits are beginning to make themselves felt and that we should not assume that anti-knock ratings can be increased indefinitely or that anti-knock rating alone is all that is required to permit increase in the compression of carbureting engines."

As to limitations, surely no one expects that anti-knock effects can be extended indefinitely. Even if they could, we must necessarily face the fact that as compression is increased to take advantage of the rising anti-detonating properties, we must inevitably arrive at the point where the temperature of compression will ignite the charge. This consideration, among others, leads to the natural speculation as to whether we are not being led to some form of ignition-compression cycle as an alternate, at least, to the use of high octane fuels.

LUIS DEFLOREZ,
New York City

* NOTE: Compare Beall, page 371, paragraph 3, 1st sentence with deFlorez, page 333, paragraph 2, 4th sentence, beginning line 11.

To the Editor, September 11, 1936
JOURNAL OF THE AERONAUTICAL SCIENCES
Rockefeller Center,
New York, N. Y.

Dear Sir:

I read with great interest Mr. de Florez' letter of June 15th and with even greater interest Messrs. Heron and Nutt's answer to it in the August issue. With regard to Mr. Heron's letter, the only thing I wondered about in it was his remark that the existing engines designed for 87 octane fuel can use 100 octane very readily. I am not so much concerned with the question of whether or not the engine will run all right on 100 octane as I am with the human nature side of it. In the first place, it is well known that the airlines are only using one tank of 87 octane for takeoff and then cruising on 80 because of expense. If, on the other hand, they could get nothing but 100 octane, it would seem reasonable to assume that they would very soon be calling for

engines that really needed 100 octane. I realize that Mr. Heron is merely speaking of a transition period, of which I will have more to say further on in this letter.

As regards to Mr. Nutt's letter, it would seem that the engine he speaks of, which has had its performance increased 43% without any increase in compression ratio and improvement in fuel must have been a pretty inefficient engine to start with or, as I suspect, the engine revolutions were considerably increased and also the blower ratio was increased, which would in effect increase the compression. In quoting Mr. Beal's letter, first paragraph, it would seem that Mr. Beal did not read Mr. de Florez' letter because he very plainly said just exactly what Mr. Beal said, that 73 octane gasoline has been produced by segregating crudes.

I was very disappointed to see that neither Mr. Nutt nor Mr. Heron answered any of Mr. de Florez' questions with regard to the cost of plants to produce 100 octane gasoline. In my business I am frequently called on to make estimates of running costs and it would be a great advantage to know what 100 octane would be bought for in the very near future. At the present moment the prices are largely governed by what the traffic will bear and have very little relation to the cost of the product. This cost is apparently charged to advertising, but if we were to be suddenly faced with a war the problem of production would become very acute. As an example, suppose we had some three thousand aircraft, which I think is a low estimate. A good percentage of these would naturally be two engine, so let us say we had some four thousand engines. The way horsepower has been jumping up in military aircraft, I think five hundred cruising hp. per engine would be a fair estimate. Let us say each engine burns .5 lbs. per hp. hour which, in spite of some tales to the contrary, they still do. This would mean slightly over forty gallons an hour per engine. Supposing each engine flew one hour a day, which again is conservative, it would mean one hundred and sixty thousand gallons of fuel per day. The problem of getting these vast quantities of fuel to the various bases would also be a very difficult one and something that should be given a great deal of consideration. It would require very large storage tanks, which would be very vulnerable to enemy bombs.

In conclusion, it would seem that the engine manufacturers and the oil manufacturers have very little understanding of each other's business and should definitely get together. It would undoubtedly be true that if 100 octane gas was to be put in immediate use by all airlines and the Army and Navy, it would require the building of special plants and undoubtedly, in time, reduce the cost. It would also tend to show whether or not the manufacture and storage of such fuel would be practical, and whether or not, as some of us think, sooner or later with the rise in compressions that will come with 100 octane fuel we would approach the compression ignition engine, and then need a fuel just the reverse of 100 octane.

JAMES B. TAYLOR, JR.
Taylor-Ainsworth, Inc.

Institute Notes

CERTIFICATE OF MEMBERSHIP

A new certificate of Membership is being prepared and will be sent to all members except Student Members without charge during October. Student Members who, after graduation, continue their membership as Technical Members, will then receive certificates.

As it is a rule of all technical organizations that certificates of membership may only be retained as long as a member is in good standing, all certificates sent should be considered as a loan to be returned upon cessation of membership for any reason.

MEETINGS

October 14-16, 1936. S.A.E. National Aircraft Production Meeting, Los Angeles.

December 4, 1936. Dinner given by the Institute of the Aeronautical Sciences in honor of Dr. George W. Lewis, at which the Daniel Guggenheim Medal will be presented to him. Hotel Biltmore, New York. During the day a joint technical aeronautical meeting of the A.S.M.E. and the I.Ae.S. will be held.

December 9, 1936. Technical meeting, Air Races, Miami, Florida.

December 28, 1936–January 1, 1937. American Association for the Advancement of Science Annual Meeting and Science Exhibition, Atlantic City.

December 29, 1936, 2 p.m. Aeronautic Meeting of the I.Ae.S., Atlantic City.

January 27–29, 1937. Annual Meeting, I.Ae.S., Columbia University, New York.

January 28, 1937. Annual Dinner, I.Ae.S., Columbia University Faculty Club, New York.

Necrology

Charles Ward Hall, a MEMBER of the Institute, died on August 21, 1936, as the result of an accident while flying from the Hall-Aluminum Aircraft Company at Bristol, Pa., to Washington, D. C.

A graduate of Cornell University in 1895, Mr. Hall had contributed papers to the National Advisory Committee for Aeronautics, the Society of Automotive Engineers and Aviation Magazine on lightweight aircraft structures, in which he specialized. He also constructed at his former plant in Buffalo and entered a special plane for the Guggenheim safe aircraft competition in 1929. Later he built a large patrol boat for the United States Navy. Of this twin-engined type, the PH-1, nine were delivered. It was followed by the XP2H-1, a patrol bomber flying boat of 112 feet wing span and speed of 140 m.p.h., one of the largest naval aircraft.

Mr. Hall was a member of the Engineers Club of New York, the Saturn Club of Buffalo, and the Society of Automotive Engineers. He held a private Pilot's license.

Exchanges

The Institute exchanges the Journal with many other aeronautical periodicals. They are kept on file at the Skyport in Rockefeller Center, New York City, where members may read them. As readers of the Journal may wish to subscribe to some of them, a list of these periodicals with their addresses is published here. Information regarding subscription prices may be secured from the Secretary of the Institute.

Aero, Maneesikatu 2, Helsingfors, Finland.

Aero Digest, 515 Madison Ave., New York City.

Aeronautica Argentina, Velez Sarsfield 57, Cordoba, Argentina

L'Aeronautique, 55 Quai des Grands-Augustins, Paris, France.

L'Aerophile, 7 Rue Saint-Lazare, Paris, France.

The Aeroplane, 175 Piccadilly, London, W.1, England.

L'Aerotecnica, Via delle Coppelle 35, Rome, Italy.

Les Ailes, 77 Boulevard Malesherbes, Paris, France.

Aircraft Engineering, 2 Bloomsbury Place, London, E.C.1, England.

Air Law Review, Washington Square East, New York City.

Asas, Caixa Postal 1967, Rio de Janeiro, Brazil.

Astronautics, American Rocket Society, 31 West 86th Street, New York, N. Y.

Aviation, 330 West 42nd St., New York City.

Aviation Weekly, 9401 Western Ave., Los Angeles, California.

L'Aviazione, Corso Umberto 504, Rome, Italy.

Boletin de Aeronautica Civil, Calle Azcuenaga 923, Buenos Aires, Argentina.

Boletin Oficial de la Direccion General de Aeronautica, Magdalena 12, Madrid, Spain.

Bulletin du Service Technique de l'Aeronautique, 72 chaussee de Waterloo, Rhode-Saint-Genese, Belgium.

Bulletin of the American Meteorological Society, Blue Hill Observatory, Milton, Massachusetts.

Bulletin Officiel du R.A.A., 6, Rue de Mezieres, Paris (6), France.

Bulletin Technique du Bureau Veritas, 31 rue Henri-Rochfort, Paris (17), France.

Canadian Aviation, Journal Building, Ottawa, Canada.

Deutsche Luftwacht, Schoeneberger Ufer 46, Berlin W35, Germany.

Les Fiches Aeronautiques, 6 rue Galilee, Paris, France.

Flight, Dorset House, Stamford St., London, S.E.1, England.

Flugwesen, Konviktska 22, Prague 1, Czechoslovakia.

Indian Aviation, P. O. Box 2361, Calcutta, India.

Journal of Air Law, Northwestern University, Chicago.

Journal of the Institute of Engineers, Australia, Science House, Gloucester and Essex Sts., Sydney, N. S. W., Australia.

Journal of Research of the National Bureau of Standards, U. S. Govt. Printing Office, Washington, D. C.

Journal of the Royal Aeronautical Society, 7 Albemarle St., Piccadilly, London, W.1, England.

Journal of Scientific Instruments, 1 Lowther Gardens, Exhibition Rd., London, S.W.7, England.

Journal of the Society of Automotive Engineers, 29 West 39th St., New York City.

Letectvi, Celetna 13, Praha I, Czechoslovakia.

Luftfahrt-Forschung, Verlag Oldenbourg, Munich 1, Germany.

Die Luftreise, Lindenstr. 35, Berlin SW68, Germany.

Luftfahrt-Literaturschau, Z.W.B. bei der D.V.L., Berlin-Adlershof, Germany.

Model Airplane News, 551 Fifth Avenue, New York City.

Model Aviation, The American Academy for Model Aeronautics, 1733 RCA Building, Rockefeller Center, New York, N. Y.

Monthly Weather Review, U. S. Dept. of Agriculture, Washington, D. C.

Motor and Flying, 24 Bond St., Sydney, N. S. W., Australia.

National Aeronautic Magazine, Dupont Circle, Washington, D. C.

Official Aviation Guide, 608 S. Dearborn St., Chicago.

The Pilot, Grand Central Air Terminal, Glendale, California.

Il Politecnico, Via Spiga 32, Milan (2/7), Italy.

Popular Aviation, 608 S. Dearborn St., Chicago.

Proceedings of Institute of Radio Engineers, 330 W. 42d St., New York City.

Review of Scientific Instruments, 175 Fifth Ave., New York City.

Revista de Aeronautica, Ministerio de la Guerra, Apartado 1047, Madrid, Spain.

Revue de l'Armee de l'Air, 55 quai des Grands-Augustins, Paris, France.

Revue du Ministere de l'Air, 71 avenue des Champs-Elysees, Paris, (8), France.

Rivista Aeronautica, Ministero dell'Aeronautica, Rome, Italy.

The Royal Air Force Quarterly, Gale & Polden Ltd., 2 Amen Corner, London, E.C.4, England.

Southern Flight, Ledger Building, Fort Worth, Texas. Texas.

Sportsman Pilot, 515 Madison Ave., New York City.

Technical News Bulletin of the National Bureau of Standards, U. S. Govt. Printing Office, Washington, D. C.

Technika Vosdushnogo Flota, U1. Radio 16, Moscow 16, U. S. S. R.

La Technique Aeronautique, 2 rue Blanche, Paris (9), France.

U. S. Air Services, Transportation Building, Washington, D. C.

Western Flying, 420 S. San Pedro St., Los Angeles, California.

Wirtschaft Technik Verkehr, Alte Jakobstr. 148/155, Berlin SW68, Germany.

Zeitschrift für angewandte Mathematik und Mechanik, Kulmstr. 1, Dresden A24, Germany.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps. The articles listed may not be obtained from the Army Aeronautical Museum Library as these magazines are available to Wright Field personnel only.

Aerodynamics

The Boundary Layer and Recent Developments. L. Bairstow. Survey from the equations of fluid motion to the calculation of profile drag and lift coefficient up to its maximum. The subjects discussed include: the assumptions of boundary-layer theory, extension of laminar boundary-layer theory to curved surfaces, maximum lift coefficient on the basis of a laminar boundary layer up to the point of separation, turbulent boundary layers, Kármán's theory of turbulence, velocity distribution for turbulent motion in circular pipes, Blasius's law for less fully developed turbulence, turbulent boundary-layer theory, and maximum lift coefficient for turbulent boundary layers. Journal Royal Aeronautical Society, August, 1936, pages 563-579 and (discussion) 579-585. 12 illus.

Critical Speeds of a Wind Tunnel Fan Shaft. J. Morris. Resonant vibration due to the frequency of the aerodynamic pulsations from the blades of the fan synchronizing with the frequency of the lateral vibration of the system appears to arise at four speeds, of which three are in the running range, and of these the highest will be the most serious. There is also a resonant vibration between a blade frequency in fore and aft vibration with the forcing vibration of frequency twice per revolution which will act on each blade. Calculations of the possible critical or resonant speeds in the design of a fan drive for wind tunnels. Journal Royal Aeronautical Society, July 1936, pages 557-560. 1 illus.

Aircraft Design

Body and Tail Moments in Spin. The importance of the shape of the fuselage cross-section on the body and tail moments in a spin. Reference is made to that portion of the British Aeronautical Research Committee Reports and Memoranda No. 1689, which deals with model experiments on the moment given by bodies of various cross sections under spinning conditions, and also with the moment given by various shapes of fin and rudder for different positions of the tailplane, the shape of which was also varied. Comparative figures illustrate the anti-spin yawing moment given by bodies of various cross sections and profiles in a spin, by the body and tail in a spin for various positions of the tailplane, and by the body and tail for various fin and rudder shapes and tailplane positions. Aircraft Engineering, August 1936, pages 221-222. 3 illus.

Comfort in Air Travel. S. J. Zand. Comfort attained in passenger airplanes in regard to noise, ventilation, changes of the attitude of an airplane (bumpiness), heat or cold, improper seating accommodation producing muscular fatigue, mechanical vibration, rate of climb or descent, altitude, and smell. Propeller and engine-exhaust noises and engine clatter are discussed and the forces acting on shear-type mountings for a 9-cylinder 750-hp. radial engine are analyzed, including vertical shear, static overhang moment, engine torque and propeller trust. Airborne sounds, ventilating noises, and sound insulation and absorption are examined and a frequency analysis given showing progress of noise reduction in an actual bi-motor 18-passenger airplane. Journal Royal Aeronautical Society, July 1936, pages 524-549 and (discussion) 549-556. 15 illus. 3 tables.

A Flying Boat with Movable Hull. In the flying boat patented by Major Rennie of the Blackburn firm, the lateral floats can be retracted into the engine nacelle in the wing and the hull raised. Drawings with brief reference. Les Ailes, July 9, 1936. page 5. 2 illus.

Study of Comfort on Board Transport Airplanes and Practical Application to an Airplane. S. J. Zand and G. Perot. Analysis of noise on board airplanes and methods of decreasing the intensity at the sources of the noise. The elastic suspension of aircraft engines, venilating and heating the cabin, materials used in the soundproofing of cabins, and application of these methods to the soundproofing of the Breguet-Wibault 670 transport plane are discussed. A plan for soundproofing, specifications, and estimates of the additional weight for soundproofing are described with results of flight tests. Long article with test results. L'Aéronautique, L'Aérotechnique Suppl., June 1936, pages 69-85. 25 illus. 5 tables.

Tests of the Gerin "Varivol" in the Large Chalais-Mendon Wind Tunnel. J. Gerin. Test results demonstrating that it is possible to employ an arrangement for varying the surface of the wing, transforming it from a wing with a very thin profile, utilizing its best fineness ratio, to another wing four times as large with a high-lift but flexible profile. Results of wind-tunnel tests and tests of the unfolding of the wings are given. The variation of the camber of the surfaces unfolded in function of the speed and some points on the polar diagram are studied. Construction of the variable surface and the mechanism for drawing it in are illustrated. L'Aéronautique, June 1936, pages 121-128. 11 illus.

Aircraft Grow Larger. R. M. Cleveland. Both Glenn L. Martin and I. I. Sikorsky are ready with complete plans for flying boats at least twice the size of their present flying product. M. Sikorsky's 55-ton six-engined flying boat will be capable of carrying 48 passengers in extreme comfort, and a crew of ten, non-stop between the United States and Europe in 24 hours. His predictions for an 80-ton flying boat are also discussed. A reference is made to the Douglas DC-4 40-passenger plane for transcontinental flight. Scientific American, August 1936, pages 72-74. 3 illus.

Institute Notes. For 15 lb. per brake horsepower, and 70 per cent power for cruising, the maximum possible gross weight of a flying boat is approximately 7,000,000 lb. and the optimum weight 3,000,000 lb.; it is shown in the example given. The cruising speed is 200 m. p. h. for the maximum case and 235 m. p. h. for the optimum case. Four power units of 50,000 hp. each would turn 5-bladed propellers of 60-ft. diameter at 280 r. p. m. Brief abstract of paper entitled "Possibilities and Problems in the Design of Very Large Flying Boats" by S. Kleinhans. Journal Aeronautical Sciences, July 1936, pages 335-336.

Orthoplane Theorems. A. F. Zahm. The orthoplane is defined as an airplane adapted to fly straight up from rest in still air. The author assumes as obvious that a suitably powered airplane can support itself directly by its propeller thrust and that in hovering with all its control surfaces in propeller slipstreams it can be securely poised by their use. He proves mathematically that a hovering aircraft cannot exert a dynamic lift exceeding its propeller thrust and shows that per unit thrust a travelling airplane supports about the same gross weight with its wings inside the propeller wash as with the wings outside. Journal Aeronautical Sciences, July 1936, pages 329-330. 2 illus.

Problems of Transoceanic Airplane. I. I. Sikorsky. A flying boat of from 40 to 60 tons, having a range of more than 4500 miles at a speed of not less than 160 m.p.h., is possible and will permit maintaining a North Atlantic service without stops on a schedule of less than 24 hours. An analysis discloses the direction in which the weight and resistance of the major parts of the S-42 Clipper would be changed if the plane were to have eight times greater weight and power, and shows the larger ship to be definitely more efficient. Journal Aeronautical Sciences, July 1936, pages 318-321. 1 illus., 4 tables.

Pursuit Airplanes. Ten. Col. G. A. D. Cosci. Armament required for pursuit planes is discussed in detail with special references to the "moteur canon," and including as examples the armament of British, French, Polish, and Czechoslovakian planes. Only a reference is made to the four machine guns of the Curtiss "Shrike." A drawing of the Oerlikon Mod. FF 20-mm. "canon" is given with an explanation of its design and a photograph of the PLZ. 24 illustrating the method of mounting the gun under the wing. The Hispano-Suiza YCRS 860-hp. engine with the Oerlikon "canon" is also illustrated. Single and two-seater pursuits are compared and the required performance and characteristics for pursuit planes in regard to visibility, horizontal and climbing speeds, ceiling, navigation, range and general construction are outlined. Characteristics and performance of the pursuit plane of tomorow are predicted. A three-page table gives the specifications and performance of two American (Curtiss BF-2CI and Boeing 281), two Czechoslovakian, six French, three British, one German, and two Polish pursuits, including the number of machine guns and small "canon." Rivista Aeronautica, June 1936, pages 277 302. 17 illus. 1 table on suppl. sheet.

Technical Notes. A new arrangement developed by H. B. Irving of the National Physical Laboratory for compensating the trailing-edge flaps considerably reduces the forces on the controls. Very brief illustrated description. Les Ailes, June 25, 1936, page 4. 2 illus.

A Wing with a Movable Covering. A wing with a covering which is movable in the direction of the displacement of the currents of air. Diagrams and brief discussion of test results. The first tests were made by J. Hubert and Gianoli in 1925. Les Ailes, July 17, 1936, page 4. 2 illus.

Wing-Fuselage Interference and Tapered Wing Roots for Low-Wing Monoplanes. A. Z. Boyajian. Fundamental concepts governing wing-fuselage interference for various types of roots. From the standpoint of interference the best wing root is one which can eliminate or reduce the advances of the breakaway or separation point, and eliminate or reduce the deadwater wake near the fuselage. Results of mutual interference between boundary layers of the wing and fuselage in the case of a straight continuous wing root with no fillets, in the case of a straight wing root with large fillets, and in the case of tapered wing roots are illustrated. Aero Digest, August 1936, pages 28-30, 58. 11 illus.

Review of Aeronautics. More than half the Progress Report of the A. S. M. E., Aeronautics Division, is devoted to a review of the activities of the Material Division of the Air Corps and the Bureau of Aeronautics. The activities of the former refer to aerodynamics and aircraft, propellers, structural development and research, lighter-than-air craft, power-plant development, material development, and equipment, while the activities of the latter cover aerology, airship design, maintenance, power plants, experiments and miscellaneous developments, ship installations, structural development, instruments, materials and accessories, specifications and standardization, aerodynamics, radio, and electrical equipment. A general review of progress in aeronautical meteorology, aerodynamics, airplane design and construction (in regard to speed and power-plant arrangements), flying boats, landplanes, autogiro, and aircraft power plants is also included. Mechanical Engineering, July 1936, pages 431-441. 10 illus.

Stress Analysis and Structures

Design of Welded Trusses. A. Vogel. Design principles and details of the Warren truss. Concluded. Welding Journal, July 1936, pages 22-26. 5 illus.

A Note on Beams Under Combined Side and Axial Loads. H. W. Sibert. A method for the stress analysis of a beam under combined side and axial loads. Journal Aeronautical Sciences, July 1936, pages 332-333. 2 illus.

Photoelastic Stress Analysis in Monocoque Construction. I. B. Yassin. Stress analysis of a monocoque fuselage construction was studied by means of the photoelastic method, including four variations, namely a model side panel without perforations, one with three round windows equally spaced, one with four round windows and a door, and one with filleted rectangular openings to compare with the more popular window shapes. Results obtained in tests at M. I. T. Journal Aeronautical Sciences, July 1936, pages 310-312. 4 illus.

Stress Distribution in Prismatic and Wedge-Shaped Structural Parts with Cross-Sectional Passages. Photoelastic tests of several prismatic and wedge-shaped structural parts giving the most important test results obtained by R. V. Baud. [V. D. I.] June 20, 1936, pages 789-790. 5 illus.

The Utilization of Creep Test Data in Engineering Design. R. W. Bailey. Rational basis for the design of parts required to operate under creep conditions and under any system of stress. Experimental data obtained from the creep of lead and steel tubes under compound stress are examined and conclusions reached regarding the dependence of creep upon shear. General relationships are suggested for creep in the directions of the three principal stresses X, Y, and Z (considered positive when tensile) representing any stress system. Tensile creep test data for design are illustrated by results obtained for a steel containing 0.5 per cent molybdenum and 0.3 per cent carbon, account being taken of the probable effect of service. Creep under diminishing stress is examined. The distribution of stress and creep in important engineering parts under compound stress, including tubes, pipes, and cylinders under internal pressure, bending moment, and torque, as well as the stress and creep distribution in rotating disks and rotors is determined. Institution Mechanical Engineers, Proceedings 1935, Vol. 131, pages 131-269 and (disc.) 269-349. 83 illus. 9 tables, 103 equations.

A Simple Design Chart for Rivets in Tension Field Webs. J. M. Jacobson. Chart providing a rapid means for the design of rivets and web in tension field beams or similar shear webs. The chart is arranged for use with 17-ST aluminum-alloy sheets and rivets, and the gage of web, rivet diameter, and rivet spacing may be determined for any shear. Conversely, the strength of any combination may be found. In addition, the curves will indicate the critical stress, that is, whether the bearing, rivet shear, or not tension gives the design value. Aero Digest, August 1936, pages 50-51. 2 illus.

Stiffness in Stressed Skins. E. H. Atkin. A method of determining the shear rigidity from experimental data on small panels. The author concludes that many types of stiffened-skin construction require stringers at such a pitch that over a considerable part of the load range the structure, although not fully shear resistant, is certainly not acting as a Wagner tension diagonal system, and that there is, therefore, a residual compressive component in the panel. Tests on panels with and without stringers show a considerable increase in rigidity in the former case. The analysis given shows that apparent agreement between experiment and the Wagner tension diagonal theory may be quite imaginary and fortuitous. The numerical correspondence as far as rigidity is concerned only occurs because the assumption of a uniform fully tension diagonal field, instead of a correctly varying field, gives more or less the same result in certain cases as the more correct point of view, which allows for the residual compression. The presence of the residual compression considerably reduces the loading on the booms or other boundary members. A solution of the differential equatin for the square test panel is given in the appendix. Aircraft Engineering, August 1936, pages 213-217, 220. 10 illus.

The Use of Tensors in Mechanical Engineering Problems. C. Concordia. Method of tensor calculus applied to the vibration problem, general equations of elasticity, forces and displacements of interconnected bodies, and gyroscopic effects. General Electric Review, July 1936, pages 335-341. 3 illus., 38 equations.

Aircraft

Studies of the Pou-du-Ciel in Polish, Dutch and Russian Laboratories. J. Angeli. Comparison of test results on the Pou-du-Ciel obtained in France, Poland, Holland, and Russia with special reference to interesting Russian results. Les Ailes, June 25, 1936, pages 4-5. 9 illus.

BELGIUM

The Lacab GR8 Multi-Seater Fighter. Belgian two-engined sesquiplane for long-range reconnaissance and bombardment has a top speed of 350 km. per hour. Details. Rivista Aeronautica, June 1936, pages 335-336. 2 illus.

CZECHOSLOVAKIA

The Bestiola B60 Towing Airplane. Construction, performance, and characteristics of the light Czechoslovakian airplane. L'Aérophile, June 1936, page 131. 4 illus.

The Zlin-XII Tourist Monoplane. A. Franchet. Light two-seater Czechoslovakian monoplane when powered with a Walter Mikron 50-hp. engine, has a top speed of 165 km. per hour. Powered with a Persy 37-45 hp. engine the plane has a top speed of 155 km. per hour. Les Ailes, July 2, 1936, page 3. 3 illus.

FRANCE

Amiot 144 Two-Engined Bomber. With the two new Gnome-Rhone 18 Lars engines producing 1300 hp. the Amiot 144 should make 400 km. per hour at 4000 m., climb to 4000 m. in 10 minutes and to 6000 m. in 17 minutes, and fly a distance of 3800 km. with a ton of bombs. Calculated performance with two Gnome-Rhône 14 Kirs engines is given as well as drawings of the parts of the retractable landing gear. L'Aéronautique, June 1396, pages 115-116. 7 illus.

French Military Aircraft. P. M. Magruder. Type, makes, armament and approximate performance of French military aircraft. General digest covering in this issue eight single-place and two two-place fighters and six multi-place fighters or combination fighter-bomber types. The unusual performance of the latest experimental models of single-seater fighters is referred to including the Nieuport 160, the Loire 250, and the Dewoitine D-513. The Dewoitine 500 and 371, the Morane-Saulnier 275, the Mureaux 180-C2 and 115-R2, the Bleriot-Spad 510, the Breguet 460, the Potez type 54, and the Amiot 143M are illustrated. To be continued. Aero Digest, 1936, pages 34-36, 58. 10 illus.

Technical Notes. The Potez 65 is a military version of the two-engined commercial P-62 and has a top speed of 300 km. per hour at 2000 m. Few details only. Les Ailes, July 9, 1936, page 4.

Two Dewoitine Prototypes. The D-331 long-distance two-engined bomber will carry four 200-kg. bombs or two 500-kg. bombs a distance of 1400 km. and return, at a maximum speed of 260 km. per hour. The H. D. 412 training seaplane should attain a maximum speed of 565 km. per hour. Very brief description with drawings of the structural details of both planes. L'Aéronautique, June 1936, pages 116-118. 10 illus.

Information. The Farman 21 large bomber has a total maximum weight of 18 tons and a top speed of 325 km. per hour at 4000 m. It is powered with four Gnome 14-KRSD 740-hp. engines arranged in tandem. Some characteristics given. L'Aérophile, June 1936, page XXIV. 1 illus.

The Romano R90 and R92 Pursuit Seaplanes. The R-90 is powered with a 650-hp. Hispano 9V engine and has a top speed of 310 km. per hour and the R-92 is powered with a 12YCrs 930-hp. engine and has a top speed of 350 km. per hour. Specifications in regard to construction, and performance given. Brief. L'Aérophile, June 1936, page 125. 4 illus.

GERMANY

Various Notes. Experimental flights across the North Atlantic are planned with the newly constructed Dornier Wal flying boat. Brief reference to a new Dornier model to be powered with eight Diesel engines. U. S. Naval Institute Proceedings, July 1936, pages 1057-1058.

Buecker Bue-133 Jungemeister Single-Seater Training Plane. The training plane described is designed especially for the training of student pilots in acrobatic flight and in diving. Brief description. Rivista Aeronautica, June 1936, pages 336-339. 3 illus.

The Dornier Do-20. The proposed new Dornier will have a surface of 450 mg., will be propelled by four 800/1000 hp. Diesel engines, will have a total normal weight of 50,000 kg., will attain 300 km. per hour, and will cover 7,200 km. Brief reference in caption of photograph of the model. Les Ailes, June 25, 1936, page 8.

GREAT BRITAIN

Blackburn's at Brough. The R. A. F.'s trusty old friend the Perth flying boat is again being turned into a flying test bench. After having been tried out with three of every sort of motor that has ever been invented, it is going to have three Napier Culverins. Brief reference in a report of a visit to Blackborn Aircraft, Ltd. Aeroplane, July 8, 1936, pages 48, 69.

The King's Cup Winner. Drawing of the Percival Vega Gull with cut-away section. Aeroplane, July 15, 1936, page 80.

Monoplania. T. James. Complete elimination of the biplane and the presence of potential world-record-breakers for speed and distance were significant features of the New Type Park at the 1936 R. A. F. Display. Lack of "canons," invisibility of the numerous guns carried by multi-gun fighters, and the divergence of opinion regarding the protection of bombers are referred to. Some details are given for the Armstrong-Whitworth Whitley, the Hanley-Page twin-engined bomber, the Supermarine Spitfire I, the Vickers Unnamed private-venture single-seat fighter, the Vickers unnamed high-performance bomber and the Westland Army Cooperation monoplane. Aeroplane, July 1, 1936, pages 21-22. 4 illus.

Our First Commercial Bomber. British Airspeed Envoy dual-purpose airplane, seven of which have been ordered by the South Africa Union Government. In less than eight hours the six-passenger commercial airplane may be converted into a bomber which does well over 200 m.p.h. Interesting features of the design are explained and methods of mounting the Armstrong Whitworth turret, guns, and bombs are illustrated. Aeroplane, July 1, 1936, pages 15-16. 9 illus.

Abolishing Tangential Take-Off. Performance of the new single-seater two-bladed jumping autogiro built by G. and J. Weir, Ltd., which was recently demonstrated in England. As a result of investigations into the whole problem of the jump, an entirely new form of rotor has been evolved which is essentially two-bladed and is called the "Autodynamic" rotor. Explanation of the ascent, given by de la Cierva in a paper before the Royal Aeronautical Society in March, 1935, is quoted with an illustration of how an inclined hinge alters the pitch to an angle of no lift when the blades swing back while being spun up. Photographs of the plane and a drawing of the controls are included. Aeroplane, July 22, 1936, pages 134-135. 8 illus.

What Hawkers Are Doing. The Hawker Hurricane new type of monoplane fighter has completed trials with satisfactory results and has been ordered in quantities for the equipment of the R.A.F. squadrons. The Gloster Gladiator four-gun fighter will shortly be in production. Brief references in a report to stockholders of the company. Aeroplane, July 22, 1936, page 137.

The Royal Inspection. In connection with a general account of the King's inspection visit, photographs are given showing close views of the Vickers Wellesley, Bristol bomber, a Hawker Demon, and a DeHavilland Rapide. Aeroplane, July 1936, pages 82-83. 4 illus.

The S.B.A.C. Party. General account of the flying display at the Society of British Aircraft Constructors' party, and 40 illustrations of the stands at the static show. Aeroplane, July 1, 1936, pages 30-32. 41 illus.

HOLLAND

Technical Notes. The new Fokker F-56 4400-hp. commercial plane will carry 56 passengers at 355 km. per hour. Brief reference. Les Ailes, June 25, 1936, page 3.

The Koolhoven FK-51 Two-Seater Military Airplane. A. Frechet. The Small Dutch biplane described is equipped with an Armstrong-Siddeley Cheetah-IX 360-hp. engine and is designed for training in military duties and acrobatics. The airplane has a top speed of over 250 km. per hour at 2200 m. and lands at 84 km. per hour. Les Ailes, July 9, 1936, page 3. 3 illus.

U. S. A.

Aeroneer I-B. The new two-place all-metal monoplane described in detail is constructed along transport lines and brings to the private pilot many features accepted as standard in large airliners and military planes. Top speed with a Menasco C-4 engine 147 m.p.h. Aviation, July 1936, pages 32-33. 5 illus.

Brown Model B-3. Chief distinction between the B-3 for the private flier and the Brown racers is the introduction of the full Handley-Page slot system in the unusually thin wing section. The plane has a top speed of 205 m.p.h. and a landing speed of 40 m.p.h. Description. Aviation, July 1936, pages 33, 35. 3 illus.

Fairchild. 1936 model of the Fairchild 45 five-place low-wing monoplane with a top speed of 180 m.p.h. Brief description. Western Flying, July 1936, pages 28, 30. 1 illus.

The Latest Hammond. Some of the new features in the revised version of the Model Y in which over 100 hours' flying without the use of rudder has been recently achieved. Brief. Scientific American, August 1936, page 94. 2 illus.

North American NA-16. Low-wing military general-purpose monoplane designed to Air Corps specifications and available in five variations—as a general-purpose plane, a two-seater fighter, a bomber, and an advanced trainer, or a single-seat fighter. Description, specifications, performance, and armament. Aviation, July 1936, pages 38, 41. 2 illus.

Aeroneer 1-B All-Metal Monoplane Powered with the 125 Hp. Menasco Model C-4 Engine. The all-metal cantilever low-wing monoplane for two is modeled after modern transport design and features stability, low landing speed and rugged monocoque construction. The plane has a top speed of 147 m.p.h. at sea level and a landing speed of 54 m.p.h. Long description. Aero Digest, August 1936, pages 52, 54, 5 illus.

Ranger-Powered Fairchild "24". Changes in the 1936 model with specifications and performance figures. Brief. Aero Digest, August 1936, page 51. 1 illus.

United States. The single-engined Northrop bomber is a two-place airplane designed for various duties. It carries a cargo of ten projectiles of 45 kg. and flies 355 km. per hour at 2000 m. with a total weight of 2900 kg. Its theoretical ceiling is 8500 m. Photograph only with brief action. Les Ailes, July 17, 1936, page 9. 1 illus.

Aircraft Manufacture

Manufacturing Facilities of North American Aviation, Inc. Floor plans of the buildings, routing of the parts, and jigs and other equipment used in manufacture are described. Reference is made to the Air Corps order for 95 basic training planes with a few words about the plane itself. Aero Digest, August 1936, pages 22-24. 7 illus.

Propellers

Airscrew Development. H. C. Watts. Progress in regard to aerodynamic design, materials, and adaptation to engine and aircraft. Wood as a material for propellers, with particular attention to the Schwarz process, and the weakness of aluminum alloy due to fatigue are discussed. Magnesium-alloy, hollow-steel and Micarta propellers are compared with those of wood and aluminum alloy. Under adaptation to engine and aircraft, the ideal propeller is indicated. Propellers with two pitches (fixed gear), variable pitch (fixed gear), fixed pitch (variable gear), fixed pitch (two-speed gear), two pitches (two-speed gear) and variable pitch (two-speed gear) are applied to the non-supercharged engine and to the engine supercharged to maintain constant power up to 20,000 ft. Each case is examined to see how nearly the propeller approaches the ideal. Journal Royal Aeronautical Society, July 1936, pages 483-510 and (discussion) 510-523. 16 illus.

Technical Notes. Before his propeller with vanes had totaled 150 hours of flight on the Morane pursuit plane, Ratier designed another new type of propeller, the first model of which has been tested on the Breda 65. The results obtained in the Italian tests have led to an order for a series of these propellers. Brief reference only. Les Ailes, July 2, 1936, page 3.

Rocket Propulsion

Liquid-Propellant Rocket Development. R. H. Goddard. A rocket chamber and nozzle can use liquid oxygen together with a liquid fuel and can exert a lifting force without danger of explosion and without damage to the chamber and nozzle, it was shown in the tests described. Rocket development carried out in New Mexico, July 1930-32 and September, 1934-35. To be concluded. Scientific American, August 1936, pages 74-79. 4 illus.

Records and Races

Distance Mark Set by Army Amphibian. World non-stop distance record for amphibians of the Douglas OA-5 type, made by Major Generals F. M. Andrews and F. R. McCoy in flying 1425 miles from San Juan, Puerto Rico, to Langley Field. Brief reference only. Aero Digest, August 1936, page 76.

The Jo'burg Race. Discussion of the London-Johannesburg Race with an explanation of the handicapping formula. Aeroplane, July 22, 1936, page 131.

Preparations for the Air Races. Plans for the 1936 National Air Races including events and some of the planes entered. Aero Digest, August 1936, page 25.

Six Heures D'Angers. Results of the annual French contest, the Douze Heures d'Angers, which was changed to a six-hour contest because of the bad weather delaying the start. Brief. Aeroplane, July 22, 1936, page 131.

The Aeroplanes in the King's Cup Race. Thirteen different types of airplanes including three new types namely the Double Eagle, D. H. Dragonfly, and the Percival Vega Gull which will race for the first time. Only three types of engines are represented and they are all DeHavillands. Brief notes about each entry with photographs. This article is followed by one giving a list of pilots entered in the race, their records and photographs, and an illustrated description of the course. Aeroplane, July 8, 1936, pages 57-65. 14 illus.

All the Winners of Fourteen King's Cups. Résumé of the fourteen King's Cup races which have so far been flown. This is followed by an article entitled "How the King's Cup Will Be Won" containing a list of entries and handicaps. Aeroplane, July 8, 1936, pages 52-55.

Mlle. Maryse Hilsz. New height record set for women and for French men, in landplanes by reaching 45,930 ft. Brief reference to plane. Aeroplane, July 1, 1936, page 2.

On the King's Cup Races—Weather or Not. C. G. Grey. An interesting Grey account of the Race with suggestions for future contests. The article is followed by a page of drawings entitled "Stable Secrets" showing features of particular interest in the racing planes, by a second article describing the events, and by photographs of the planes and pilots participating. Aeroplane, July 15, 1936, pages 85-102. 36 illus.

Engine Design and Research

1936 Summer Meeting Papers in Digest. Acoustics, fuel characteristics, engines, propellers, Diesel cooling and fuels, aircraft construction, aircraft engines, and aircraft fuels are the subjects covered principally in the very brief abstracts given. S. A. E. Journal, July 1936, pages 33-38.

The Development of "Proferall" Cast Camshafts. D. J. Vail. The test results described were obtained with camshafts of "Proferall," a processed-ferrous-alloyed iron made by the duplexed electric-furnace process. Composition, Brinnell hardness, and torsion and tension test data are included. The series of tests were equivalent to runs of 46,560 miles and showed that both chemical analysis and hardness affect camshaft-gear wear. Comparative wear tests on bearings indicated more than three times as much wear on steel camshafts as on the cast ones. Other tests showed that the cast shafts expanded less than those of steel. Advantages in manufacture also are given. S. A. E. Journal (transactions) July 1936, pages 288-291 (discussion) 291-292. 1 illus.

Direct Fuel Injection with Spark Ignition. G. W. Ball. Advantages of fuel injection directly into the cylinder and with spark ignition are outlined and compared with the present limitations. Results of tests at M.I.T are referred to and test results obtained in a Government laboratory on two multi-cylinder fuel-injection engines are discussed in detail. A projected investigation to determine the ideal design characteristics for such an engine is outlined and future developments in aircraft-engine design are predicted. Advantages and disadvantages of manifold injection are pointed out and the problems of fuel-flow control in an aircraft engine are taken up. Aero Digest, August 1936, pages 42, 44, 46, 48, 84. 8 illus., 2 tables.

Engine Types and Requirements for Preparation of Fuels. F. C. Mock. Adoption of fuel injection is considered an absolute necessity for further development of the aircraft engine and the immediate benefits available are said to be increased power, reduction in fuel consumption, and diminution of intake ice. Cylinder injection will give improved local cooling of present hot-spots in the cylinder and perhaps larger displacements per cylinder. The discussion covers requirements for proper preparation of the fuel charge for rapid combustion in present engines, engine types determined by fuel volatility, considerations for different fuel volatilities, timed injection into intake pipes, cylinder injection with spark ignition, and compression ignition. A cylinder type for reducing detonation is illustrated in which injection occurs near the end of the compression stroke. S. A. E. Journal (Transactions) July 1936, pages 257-264 and (discussion) 264-266. 11 illus.

Fuel Injection with Spark Ignition. A seven-cylinder radial engine developed by G. Voisin for his "automobile of the future," an injection system for aircraft engines developed by M. Lauret which is similar to the Pratt and Whitney method, and the system of heavy-fuel injection developed by Rochefort are briefly described. A reference is made to a method developed by a French concern in which the spark plug is used as a means of combating ignition lag. Abstract from the Journal of the Society of (French) Automobile Engineers. Automotive Industries, August 8, 1936, pages 186, 192.

Liquid-Cooled Aero Engines. H. Wood. Development of the Rolls Royce Kestrel engine, a reference to the Merlin engine, and an analysis of the requirements for the high-performance engine of the future which should develop at least 1500 b. hp. and should operate on fuels of high knock ratings. Engine form, fuels, detonation, waste-heat disposal, cooling drag, cooling medium, and mechanical and operational features are discussed. The author concludes that compression ratios, charge density, and rotational speeds will need to increase. Therefore cylinder bores and strokes will decrease and it may be necessary to adopt the sleeve-valve type. Arrangement of the engine will tend to multithrow crankshafts with more than two pistons per crankpin. It will be necessary to abandon methods of cylinder construction that rely on the art of the pattern maker and founder in order that cooling passages may be better controlled in cross-sectional area and in order that more uniform metal sections may be secured to reduce heat stresses and weight. A more exact method of assessing knock ratings is required for complete knowledge of the fuel's performance in the actual aero engine. It will be nec-

essary to liquid-cool the engine in order to deal with the increased waste heat, and to operate the cooling medium at a high temperature in order to keep the cooling drag within reasonable limits. In the discussion following the paper Mr. Wood's experience with aromatic fuels is confirmed by Lieut. Klein with a reference to Air Corps tests, and Mr. Wood's conclusions on radiator proportions are refuted by W. Worth of the Materiel Division. (Note:—This description of the Rolls Royce engines is said to include facts not previously released in England.) S. A. E. Journal (Transactions) July 1936, pages 267-286 and (discussion) 286-287. 33 illus.

Comparative Tests of the Combustion and Work Processes for Engines Employing Various Systems of Operation. A. F. Schmidt. The relation of fuel consumption, obtainable mean pressure and maximum pressure in the cylinder for various combustion processes are explained and compared with values for engines not subject to loss. On the basis of the determined theromodynamic efficiency, the possibility of the formation of the engine processes under the various requirements of performance and consumption is indicated and the possibilities existing for further improvement are pointed out. The influence of ignition delay on pressure and combustion is given and the particular influence of various final compression temperatures and various pressures of the intake air are demonstrated. By means of more recent test methods, and in particular, by the additional recording of pressure differences on the indicator diagram, a contribution is made towards an explanation of the processes in Diesel engines with subdivided combustion chambers. V. D. I., June 20, 1936, pages 769-779. 22 illus.

Damping Influences in Torsional Oscillation. J. F. Shannon. Damping influences occurring in multicrank engines when in a state of torsional oscillation. The major part of the experimental work described was carried out on a four-cylinder gasoline engine, and a Geiger torsiograph was used to examine conditions of resonance. Extreme methods of lubrication were adopted, and the outstanding influence of lubrication in the control of amplitude at resonance is demonstrated. For the engine dealt with, the principal source of damping is traced to the main bearing. The dissipation of energy in an oil film, due to journal vibration, is examined analytically and expressed in terms of journal displacement. From an investigation of journal displacements caused by crankshaft oscillation, it is found that practically all the input energy of vibration could be accounted for in this manner. Results are reduced to an overall non-dimensional factor which is practically constant for the range of frequencies investigated. The value of the factor is not constant for different engine systems but appears to be correlated to the elastic curve form at the engine, and an average curve form taken on this basis is presented as a guide in design. Institution Mechanical Engineers, Proceedings 1935, pages 387-436 and (disc.) 436-492. 46 illus. 6 tables, 24 equations.

Cylinder Temperature. M. O. Teetor. Thermal distortion and inadequate lubrication resulting from localized hot spots due to insufficient cooling. A typical example of what happens to a cylinder barrel having a localized hot spot is given and lubrication of the cylinder wall discussed. Brief abstract of paper presented before the S. A. E. Oil & Gas Journal, July 23, 1936, page 43.

Gas Pressure Behind Piston Rings. Indicator diagrams of the gas pressures in the grooves behind the rings during the working cycle are given and explained. Automotive Industries, July 25, 1936, pages 118-119. 3 illus.

Heat Rejection from Diesel Engines. M. S. Huckle and H. V. Nutt. Effect on heat rejection to the cooling water of spark ignition versus compression ignition, exhaust-manifold and lubricating-oil cooling, load, injection timing, engine speed and type of engine. Brief discussion of test results. Short abstract of paper presented before the S. A. E. Oil & Gas Journal, July 23, 1936, page 43.

Note on Effect of Cylinder Head Design on Detonation. C. F. Taylor and G. L. Williams. Design of the M.I.T. detonation indicator or knockmeter, and results obtained with it in tests. The effect of a pocket opposite the spark plug seemed to be not only a substantial increase in the allowable compression ratio, but also a distinct change in the nature or mode of vibration of the gas in the cylinder. The effect of the size of the pocket on the compression ratio for incipient detonation for several fuels is discussed, and the results obtained with an oblong combustion chamber are compared with those found with the conventional cylindrical combustion chamber. Journal Aeronautical Sciences, July 1936, pages 313-315. 6 illus.

Spark Control of Supercharged Aircraft Engines. E. S. Taylor, K. F. Ku and W. P. Kennedy. By employing suitable means of controlling the spark advance critical altitude power may be maintained down to sea level without increased cylinder-head temperatures, and if cylinder-head temperatures are not excessive, power at sea level may be about 40 per cent greater than power at a critical altitude of 15,000 feet. Results of a series of tests made at M.I.T. to determine what the limitations on output would be with the detonation limitation removed by retarding the spark. The effect upon heat rejected to the cylinder walls and maximum pressure were investigated. Journal Aeronautical Sciences, July 1936, pages 326-328. 4 illus., 1 table.

Variable Timing for Two-Stroke Engines. J. H. Venediger. Output and fuel economy of two-stroke engines would be improved if the timing could be varied in accordance with the speed of operation. Practical timing possibilities where cylinder ports and rotary valves are used in conjunction in two-stroke engines are discussed. Port area-time integral curves and timing diagrams are given. Long abstract from Automobiltechnische. June 10. Automotive Industries, July 25, 1936, pages 120-124. 9 illus.

A Visual Study of Air Flow, Fuel Spray, and Flange Formation in a Displacer-Piston Compression-Ignition Engine. A. M. Rothrock. While the core of the fuel spray was not destroyed by the air movement, the direction of the spray was changed and the spray envelope was carried away by the moving air. Brief review of test results obtained. Short abstract of paper presented before the S. A. E. Oil and Gas Journal, July 23, 1936, page 43.

Materials for Exhaust Valves. E. Schmidt and H. Mann. Exhaust valves such as those used in aircraft engines are discussed, the stresses to which the valves are subjected are analyzed, and suitable valve materials are proposed. Heat and mechanical stresses, and the chemical stresses due to the combustion gases are pointed out and the damages in operation due to nature of the material and construction are described. Properties of valve materials in regard to composition, structure, resistance to heat, behavior against corrosion and scaling, and heat conductivity, as well as methods of forming the materials are taken up.

The means discussed for increasing durability and protection in operation include: increasing the resistance to heat scaling and corrosion by the use of certain alloys and improvement of heat conductivity; decreasing the wear and tear on the valve seat and the valve stem by measurements of the valve and by modulating the materials for valve guides and seats; and improvements in the supervision of valve production. Automobiltechnische Zeitschrift, June 25, 1936, pages 302-312. 19 illus., 3 tables.

Simulated Leakage Gages Ability of Spark Plugs. E. A. Keeler. A convenient and reliable method for comparing the sparking abilities of various spark plugs and electrode alloys was determined in the investigation described. Plugs were operated on a C.F.R. engine with resistance shunted across their terminals and those sparking with least resistance had the highest ability. Results are given which were secured in a comparison of three well-known spark plugs of the conventional double-electrode type with a plug of the surface-sparking type using a long gap (0.075 in.) partly traversing the tip of the insulator. Effects of fuel and mixture richness, ethyl gasoline and intake temperature on sparking ability are shown. Automotive Industries, August 8, 1936, pages 182-184. 8 illus.

Turning in Technical Lanes Marked at Summer Meetings. Outstanding events at the Summer Meeting and a review of the papers and discussions. S. A. E. Journal, July 1936, pages 13-25, 41-44, 48, 50, 52, 54, 56.

Whither the Liquid-Cooled Aero-Motor? Figures for the Rolls-Royce Merlin engine, given in the paper which H. Wood presented before the S.A.E., had not previously been released in England. Criticism of the paper and quotations from the conclusions. The new Gallay dual-stage oil cooler, the Robertson cooler, and the latest Serck oil cooler are illustrated. Aeroplane, Aeronautical Engineering Suppl., July 22, 1936, pages 123-126. 4 illus., 1 table.

Cooling

Cowlings for Controlled Circulation. H. Paupert. In a general discussion of radial-engine cooling problems, an arrangement of vanes on the solid ring of the propeller is proposed in order to control the flow of air under the cowling for cooling the engines. Each vane would turn around a radial axis and the size and spacing of the vanes would be determined by the conditions that, in rotation around their respective axes, they can nearly block the orifices of the air inlet. The N.A.C.A. cowling and the Townend ring are discussed, reasons for controlling the circulation of the air are explained, and the motive pressure calculated. Les Ailes, July 2, 1936, pages 4-5. 13 illus.

Ducted Radiators. F. W. Meredith. The theory of low-velocity cooling with a basis for calculating the drag. The radiator is considered as an actuator disk operating on a perfect fluid, for the freely exposed radiator, and the theory is extended to the case of a radiator in a duct. Effects of compressibility of the air, rise of apparent air temperature with speed, increased power absorption of the hot radiator, the effect of heat on the available energy of the issuing stream, quantitative balance of the power in the duct, applicability of the theory to an actual installation, and the effect of the momentum of the exhaust gases on the drag of an engine installation, are discussed. R. & M. 1683 "Note on the Cooling of Aircraft Engines with Special Reference to Ethylene Glycol Radiators Enclosed in Ducts," slightly abridged. Aircraft Engineering, August 1936, pages 218-220. 2 tables, 30 formulas.

Engine Materials

Metallurgical Problems of Aero Engine Manufacture. E. R. Gadd. More important components of the aircraft engine are discussed with regard to metallurgical properties and reasons given for the development or selection of the materials now used for their specific purposes. Materials for pistons, cylinder heads, crankshafts, connecting rods, high-tensile bolts, valve seats, valves, crankcases, valve springs, aluminum alloys for high temperatures, and the problem of fretting and warting are taken up with references to production methods. Journal Royal Aeronautical Society, August 1936, pages 622-633. 4 illus., 5 tables.

Engines

Gnome Rhône 1400-Hp. Radial Aircraft Engine. The two-bank 18-cylinder engine briefly described is said to be the most powerful radial aircraft engine built. It recently passed its type tests at the Service Technique de l'Aéronautique Français. Crankshafts, cylinders, the redesigned rear section of the crankcase, and the supercharger are covered but no mention is made of performance. Automotive Industries, August 8, 1936, pages 189, 195. 1 illus.

Junkers Adopts Fuel Injection on Two-Cycle Engines. Fuel injection has been adopted for the Junkers two-cycle gasoline engines with the object of achieving a reduction in the specific fuel consumption, lightening the power plant, and, in the case of aircraft engines, or reducing the torque impulses. Brief reference only to the six-cylinder engine designed for direct injection of gasoline. The injection system is said to be similar to that used on the Junkers Diesel. Automotive Industries, August 8, 1936, page 194.

The Rolls-Royce Merlin Engine. Fitted in the Hawker Hurricane and Supermarine Spitfire low-wing monoplane fighters, this 12-cylinder vee water-cooled, geared and super-charged engine is reputed to develop 1000 hp. Photographs only. Aircraft Engineering, August 1936, page 223. 3 illus.

Technical Notes. Comparative temperature tests were carried out by Air France on the Potez 62 with the normal K-14 engines and with K-14 engines modified by very thin and very closely spaced fins, according to the new American technique, which permits an increase of cooling surface of the cylinders. The compression ratio was raised to 6.1. A few results are given. Les Ailes, June 25, 1936, page 3.

The Train 6-T 60/70-Hp. Engine. A new six-cylinder in-line air-cooled aircraft engine which develops 60 hp. at 2300 r.p.m. Few details. Les Ailes, June 25, 1936, page 11. 2 illus.

A Double Governor is Provided on the Ex-Cell-O Injection Pump for Diesel Engines. The quantity of fuel injected is controlled at high speeds by the centrifugal force on governor weights, and at low speeds by the vacuum in the inlet manifold. Design and operation of the Diesel injection pump are explained with drawings. Automotive Industries, July 25, 1936, pages 128, 132. 2 illus.

Hot Spark for Oil-Burning Engines. Special ignition system for heavy-duty oil-burning engines and for engines using a low grade of fuels has been placed on the market by Mallory Electric Corporation. Description. Automotive Industries, July 25, 1936, pages 117, 131, 132. 5 illus.

Menasco Engines. Pirate C4S 4-cylinder and Buccaneer B6S 6-cylinder air-cooled in-line inverted engines to be produced commercially. Description with performance curves for the C4S and altitude performance curves of the supercharged B6S. Aviation, July 1936, pages 35, 37. 3 illus.

Modern Wizardry. The Rolls-Royce Merlin of unspecifiable output is shown without the cowling. The engine is considered to give more power for its weight than any other liquid-cooled engine. Photographs only. Aeroplane, July 8, 1936, page 46.

The Three LeBlond Engines. J. G. Thompson. Maintenance methods for the LeBlond Models 60, 70 and 85 engines. Western Flying, July 1936, pages 19, 20, 22.

Turbines

Utilization of Steam Turbines in Aeronautics. M. Précoul and M. B. Rabinovitch. Steam turbines for powering airplanes are compared with the airplane engine of today and the advantages of the turbine in regard to its increased efficiency with increase in altitude and to its faculty for overloading are discussed. L'Aérophile, June 1936, pages 132-133. 3 illus.

Engine Testing

A New Test Bench for Engines. A. E. Test bench for engines up to 700 hp. with a reference to a supplementary impeller with two blades for use with engines up to 1200 hp. Very brief description. L'Aérophile, June 1936, page XIII. 2 illus.

Sapphire and Other New Combustion-Chamber Window Materials. G. Calingaert, S. D. Heron and R. Stair. Materials available and suitable for the construction of transparent windows for observation inside of the combustion chamber. Construction of the windows briefly referred to. Short abstract of paper presented before the S.A.E. Oil & Gas Journal, July 23, 1935, page 43.

Fuels and Lubricants

Alcohol as Motor Fuel. Production of alcohol motor fuels in Czechoslovakia (with a very brief reference to recent studies in the Polish aviation institute considered important by Czechoslovakian aviation authorities) and production of materials for alcohol-base motor fuels in Italy. Tables for all countries show alcohol consumed in motor fuel and laws on blending alcohol in motor fuel. Industrial & Engineering Chemistry, News Ed., July 20, 1936, pages 277-279, 3 tables.

Effect of Detonation on Oil Consumption. H. A. Everett and J. J. Mikita. Oil consumption increases materially when there is detonation, it was proved in the research described. In the first series of tests detonation was accomplished by increasing the spark advance and in the second by altering the fuel. Brief discussion of results of Pennsylvania State College tests carried out in cooperation with the Pennsylvania Grade Crude Oil Association. Short abstract of paper presented before the S.A.E. Oil & Gas Journal, July 23, 1936, page 43.

Letter to the Editor. L. DeFlorez. Engine designers are not viewing the problem of high-octane gasoline with sufficient seriousness. The equipment for large production cannot be brought into existence immediately. If such fuels are to be used for war-time purposes it is necessary to go slowly in the manufacture of engines until an adequate and wide-spread supply is available. Among the questions presented the author asks, "What would be the daily requirements of gasoline for 4000 military airplanes in time of war?" Journal Aeronautical Sciences, July 1936, pages 333-334.

Anti-Detonation Quality of Fuels. A new scale for the anti-detonating quality of fuels for carburetor engines, developed by M. Serruys, yields a synthetic index of the fuel, a factor which is claimed to be representative of the performance which may be expected from the fuel. Brief description of this method with criticisms of the octane-number system. Abstract from Genie Civil, March 21. Automotive Industries, August 8, 1936, page 186.

Extreme-Pressure Lubricants Testing. G. L. Neely. Necessity for extreme-pressure lubricants and the machines most commonly used to evaluate them are discussed. Examples are given to illustrate the differences in test results caused by differences in operating conditions, by the type of machine used, and by the method of machine installation. The new S.A.E. extreme-pressure-lubricants tester is described. Results obtained in the laboratories of the Standard Oil Company of California. S. A. E. Journal (Transactions) July 1936, pages 293-296. 8 illus.

Instruments

Sextant for Aircraft Use. Hagner Position Finder developed by the Fairchild Aerial Camera Corp. This is a navigation instrument which automatically and quickly solves the spherical triangle, and with which it is possible to secure a fix in less than two minutes. Few details only. Aero Digest, August 1936, page 62. 1 illus.

Navigation Instruments. Pioneer adjustable altimeter, the Jaeger and B.B.T. speed calculator, the "Richer-Protche" course calculator, the A. Smith course and distance calculator, and the Du Cluzel calculator. Brief illustrated descriptions. L'Aerophile, June 1936, pages 134-135. 5 illus.

Acoustics

Exporting the Art of Soundproofing. Soundproofing the French Bréguet-Wibault 18-passenger transport as carried out by Dr. Zand. Brief. Scientific American, August 1936, pages 93-94. 2 illus.

Airport Equipment

Airport Equipment. Lighting, heating, emergency, radio, and fencing equipment and hangars, trucks, and tractors for airports are reviewed and illustrated. Aviation, July 1936, pages 72-74, 78, 79, 81, 82, 85, 86. 41 illus.

Cornell Develops New Fire Door. Self-closing vertical-lift fire door is briefly described in which the operating speed is under control at all times. The door was developed by Cornell Iron Works and designed for the Navy for an airplane factory. Iron Age, July 23, 1936, page 54. 1 illus.

Movable Tanks for Refueling. A system of furnishing gasoline to airplanes, which is in use in France and was patented by E. Piquerez, consists of a series of movable cylindrical tanks which may be stored under ground, rolled around the field, or loaded on, or hauled by trucks. Rivista Aeronautica, June 1936, pages 366-372. 8 illus.

A Special Crane for Flying Boats. F. Aimond. Design and some dimensions of 10-, 20- and 40-ton cranes adopted by the French Air Ministry for handling large flying boats. Rivista Aeronautica, June 1936, pages 350-352. 3 illus.

Systems of Signaling and Illumination for Airports and Airways. M. E. Paszkiewicz. Methods of marking and illuminating airports, indictating the direction and force of the wind, marking and illumination of the airway, and systems of radio signaling and guiding and landing airplanes through fog. Rivista Aeronautica, June 1936, pages 355-366. 7 illus.

Water Won't Burn. So it's a Good Idea to Keep It Out of Gasoline. S. P. Johnston. Methods of avoiding water contamination of fuel at airports and mobile fueling and servicing units, including a drawing of the unit developed for the airlines by the Columbian Steel Tank Company. Aviation, July 1936, pages 18-20. 2 illus.

Vertical Lift Fire Door. The self-closing vertical-lift fire door described was developed by the Cornell Iron Works for the Naval aircraft factory. It has controlled operating speed and can be instantly reset after an emergency closing. Few details only. Aero Digest, August 1936, page 62.

Miscellaneous Equipment

Air Conditioning Transport Planes. Lipman refrigerating and air-conditioning device developed by General Refrigeration Corporation and used by American Airlines and T.W.A. Few details only. Aero Digest, August 1936, page 64. 1 illus.

Another Type of Ball Bearing. The new Fafnir group of ball bearings combines internal self-alignment with double grease-shield protection and has been developed primarily to meet requirements of the aircraft industry. Brief description. Automotive Industries, August 8, 1936, page 199. 1 illus. Aero Digest, August 1936, page 64. 1 illus.

Character of Light from Mercury Lamps Alone and in Combination with Tungsten Lamps. A. H. Taylor and G. P. Kerr. Data given for the distribution of energy and light in the visible spectrum for three types of mercury lamps, tristimulus specifications for various light sources, and combinations of tungsten and mercury lamps on an equal lumen basis. General Electric Review, July 1936, pages 342-343. 2 illus. 3 tables.

Jungle Emergency Landing Kits. Emergency kits which are to be standard equipment for all Army pilots making flights over jungle country. Brief description. Western Flying, July 1936, page 18.

Metals

Alloy Tubes for Aeroplanes. G. Evans. The processes described for manufacturing non-ferrous alloy tubes for airplane construction include the casting of alloy billets, vertical extrusion press, rotary piercing mill, the cold drawing process, annealing and pickling, the endless chain draw bench, and straightening, inspection and testing. Aircraft Engineering, August 1936, pages 224-226. 9 illus.

Bearing Metal of a Copper-Zinc-Tin Base. F. Hanson. Structure and sliding characteristics of these bearing metals, influence of tin, and field of application of the special alloys. V. D. I. June 27, 1936, pages 807-808. 4 illus. 2 tables.

Strength of Metals in the Light of Modern Physics. H. J. Gough and W. A. Wood. Recent work on the deformation and facture of metals in which precise methods of x-ray diffraction have been employed in order to make a systematic study of the changes produced in the crystalline structure of metals subjected to static-tensile and static-torsional stressing, also to three types of cyclic stressing or fatigue. It is shown that failure under static and fatigue stressing is associated with changes in the crystalline structure which are identcal. In order to show the relationship between the new work described and previous work dealing with the use of x-rays in studying the deformation characteristics of metals, a preliminary section of the paper deals with cold-rolling and drawing. A survey is also presented of the present position regarding strength and atomic structure, together with references to various theories regarding the imperfections of crystals as encountered in practice. An introductory section describes briefly the atomic structure of metals, as revealed by x-rays. Journal Royal Aeronautical Society, August 1936, pages 587-616 and (discussion) 616-621. 38 illus.

New Valve Steel for High Compression Engines. Silcrome X series of valve steels developed by the Ludlum Steel Company for valves for truck, airplane, motorcycle and marine engines. Information on the various grades. Automotive Industries, July 25, 1936, page 124.

Textiles

Fabric in Shear. An experiment is described in connection with Professor Wagner's theory for the use of thin sheets in spar webs in which the shear is carried by a diagonal tension stress combined with a compressive stress in vertical stiffeners. Aircraft Engineering, August 1936, pages 227-228. 4 illus.

Testing of Materials

New Hardness Tests of Materials. Various types of Brinell hardness tests are reviewed and the "Duroskop" method of determining surface hardness by dynamic tests are described. The surface hardness of all metals from soft lead to hard steel may be estimated by means of this device and, in the case of homogeneous materials, the compressive strength and elastic properties may be tested. Automobiltechnische Zeitschrift, June 25, 1936, pages 314-315. 9 illus.

X-Ray Inspection of Aircraft. H. R. Isenburger. Practically every aircraft factory abroad is equipped with x-ray apparatus but no aircraft factory in this country is equipped with radiographic units, although some light-metal foundries are x-raying their castings. Reference is made to literature on x-ray work in the aeronautical field. Portable x-ray equipment suitable for this work, and requirements for final inspection of an assembled airplane are briefly reviewed. Aero Digest, August 1936, pages 26-27. 5 illus.

The Teledeflectoscope. W. Klemperer. The instrument described was used in measuring the flexure of long beams from a remote observation station through a telescope and was developed during the construction of the Macon airship. The instrument may also be used to measure deflections at more than one intermediate point along the bay. Journal Aeronautical Sciences, July 1936, page 331. 2 illus.

Magnaflux Inspection Methods in Airplane Engines. H. J. Noble. Application of the Magnaflux process in the Pratt-Whitney plart for locating defects in magnetized steel or its magnetic alloys by means of a finely divided paramagnetic material, with reference to some of the peculiarities and limitations encountered. Comparison of wet and dry methods, overcoming magnetizing difficulties, and some types of defects found are discussed. Metals and Alloys, July 1936, pages 167-170. 8 illus.

Radio

Blind Landing. Two types of blind landing equipment installed at the Indianapolis Municipal Airport including the Bureau of Air Commerce's curved beam and the Army's directional beam-altimeter system. Brief reference only to the comparative tests and short description of the Metcalf blind landing system which consists of installation on the ground of three sources of radiation—light, radio, and infra-red. Aviation, July 1936, pages 45, 47.

Coming in to Land—Blind. T. Lee, Jr. "Visual or facsimile broadcasting will tend further to fix responsibilities by removing human error from communications between ground and planes." The "radio pen" development of J. V. L. Hogan and H. J. Miller, the "lawnmower" recorder of J. C. Young developed for the RCA, and the Otho Fulton "Fultongraph" methods of radio transmission and reproduction which are believed valuable in giving the pilot printed orders. An example is given of a plane coming in to land using the new type of radio marker being installed by the Bureau of Air Commerce at terminal stations. Captain Hegenberger's system, developed by the Air Corps, is described, compared with the Bureau's system, and criticized. An example of landing with this system is given. Western Flying, July 1936, pages 11-12, 22. 2 illus.

Foreign Service News. A German model airplane controlled by wireless made a flight of 104 seconds and answered perfectly to the control in a recent exhibit in Berlin. Brief reference also to two German aircraft carriers. Aeroplane, July 1, 1936, page 11.

Lear-O-Phone. Model L-15 new compact light-weight aircraft radio transmitter with an output of 15 watts, 100 per cent modulated. Few details. Aviation, July 1936, page 43. 1 illus.

RCA Receivers. Models AVR-7B and AVR-7C aircraft radio are two-band heterodynes both covering the 200-240 kc. frequency band for beacon and weather reception. The second band in the AVR-7B is 550-1500 kc. (broadcast entertainment) and in the AVR-7C is 2200-6700 kc. (communications). Brief description. Aviation, July 1936, page 43. 1 illus.

Radio Echo Altitude Meter. E. F. Alexanderson. In the device described a gong signals to the pilot when the airplane crosses the 1000-foot level from the ground, and the next warning is given when the 600-foot level is reached. The radio receiver is so designed and adjusted that it radiates a wave towards the ground and simultaneously receives the echo reflection of this wave returning from the ground. Results of flight tests with the radio altimeter are described by F. G. Patterson. Journal Aeronautical Sciences, July 1936, pages 316-317. 3 illus.

Aircraft Receiver. The Western Electric 20 type small light-weight radio receiver for aircraft allows convenient installations in small planes and provides the private pilot with reception in the beacon, broadcast and short-wave bands employed for communication with ground stations. Few details only. Aero Digest, August 1936, page 64.

Auxiliary Antenna. An auxiliary aircraft radio antenna designed to supplement the standard trailing antenna for simultaneous or independent use. Development completed in the maintenance department of T.W.A. Few details only. Aero Digest, August 1936, page 62. 1 illus.

Currents. Operations performed by the British Queen Bee pilotless airplanes when directed by radio are very briefly referred to. Les Ailes, June 25, 1936, page 6.

The New RCA Aircraft Radiocompass. A. M. Harned. The new RCA Model AVR-8 radiocompass has a bomb loop and furnishes both visual and aural reception. The unit is said to be a three-in-one radio aid offering: a conventional aural receiver to bring in the beam, broadcasts and weather reports; a radio compass with simultaneous visual course indication and aural reception; and aural reception operating from an electrostatically shielded loop antenna. A rotatable loop is available to further provide for determination of the plane's position by cross bearings. Long description with diagrams of the installation. Aero Digest, August 1936, pages 38, 40. 3 illus.

Air Forces

For Controlled Publicity on Air Armaments. Criticism of the "Aircraft Year Book for 1936," edited by the Aeronautical Chamber of Commerce, and a table of the relative combat airplane strength. L'Aéronautique, June 1936, pages 113-114.

FRANCE

A Day with the Military Parachutists at Pujaut. Commandant A. Langeron. A visit to the Centre des Parachutists de l'Armée de l'Air and a description of Captain Geille's descent of 35 m. in less than 5 seconds. Les Ailes, July 2, 1936, pages 6, 8. 3 illus.

"Nationalization" of the Aeronautic Industry Menaces the Development of Our Aviation. G. Houard. Proposed nationalization of the French aeronautic industry is discussed and its possible effect on French aeronautical development predicted. Les Ailes, July 2, 9, and 17, 1936, page 13.

Foreign Service News. The Air Force of France is to be divided into five Commands with headquarters at Paris, Dijon, Tours, Aix-en-Provence, and Algiers. Brief reference. Aeroplane, July 1, 1936, page 11.

GREAT BRITAIN

Anti-Aircraft Co-operation. Civil aircraft will do about 4,000 hours of flying this year in anti-aircraft co-operation. Civil machines are now engaged for target and searchlight practice and for co-operation with the Observer Corps. Brief reference only. Aeroplane, July 8, 1936, page 51.

Facts and Fiction. Chapters in Brassey's Naval Annual 1936 dealing with British naval air progress, foreign fleet air arms, the meaning of air strength to a fleet, air operations on the trade routes, United States Naval aviation, Naval aircraft production, and flying boats are criticized, especially for their anti-R.A.F. propaganda. Aeroplane, July 1, 1936, page 6.

On the R.A.F. Display. C. G. Grey. A typical Grey discussion quoting Lord Londonderry's speech exposing Mr. Baldwin's ignorance about relative air strengths in Europe before the R.A.F. expansion began, and only brief references here and there to the Display. Photographs of a few of the military airplanes are included. Aeroplane, July 1, 1936, pages 17-20. 7 illus.

The Seventeenth R.A.F. Display. C. M. McAlery. General account of the Display with reference to Army Cooperation pick-up of messages and release of supplies by parachutes, demonstration of flight aerobatics described to the audience by the leader of the formation by means of the radio, from the plane, low-bombing attack on a marauding tribe, smoke writing, and a defense exhibition. Photographs illustrate some of the events and seven of the early types of airplanes. Aeroplane, July 1, 1936, pages 23, 26-29. 11 illus.

The Supplementary Estimates. The total of £11,700,000 in the supplementary Estimates for the British Air Services is almost wholly accounted for by an additional allowance of £8,055,000 for progress payments on aircraft and engines to be delivered in subsequent years, and another £2,750,000 to cover expenditure on airports and buildings. A sum of £530,000 is allowed for the erection of new factories for the production of airplanes and engines. Strength of the R.A.F. will be increased by an extra 5,000 during the year and an extra £70,000 for training of reservists marks the intention of the Air Ministry to increase the intake into the R.A.F. Reserve from 200 to 800 a year. An appropriation-in-aid amounting to £506,000 represents progress payment on air craft to be delivered in large numbers to the Fleet Air Arm in the next two years. Army, Navy and Royal Ordnance Factories, supplementary estimates are also given. Aeroplane, July 15, 1936, page 80.

The Training Command. A few more details about the organization of the British Training Command. Aeroplane, July 1, 1936, page 9.

Aviation. Sir Roger Keys on the Fleet Air Arm, the new Ostmark catapult ship, plans for building a new airship 850 feet long and 145 feet in diameter at Akron, four model pursuit ships received by the Material Division for testing, and the new Chance Vought experimental two-place airplane designed for competitive tests on scout bombers for carrier use are briefly referred to. U. S. Naval Institute Proceedings, July 1936, pages 1067-1070.

Flying Boats Replace Seaplanes. Change about to be made in the equipment of fighting ships of the British Navy fitted with aircraft. Brief. U. S. Naval Institute Proceedings, July 1936, pages 1050-1051

PHILIPPINES

Foreign Service News. An air force is part of the new armament plan of the Philippine Government, the armament plan involving a yearly expenditure of about £16,000,000. Brief reference. Aeroplane, July 1, 1936, page 11.

Armament

Armament of Our Military Airplanes. Armament for a military airplane. Development of airplane armament is traced and the different factors concerned in the selection of armament, as well as the question of whether large carriers can be effectively protected against the attacks of the airplane cannon are briefly discussed. L'Aérophile, June 1936, pages 123-125.